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REPORT ON THE BACTERIOLOGICAL QUALITY OF THE DETROIT RIVER 1975 - 1984

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Ontario Ministry of the Environment

J. Bishop, Director
Water Resources Branch

REPORT ON THE BACTERIOLOGICAL QUALITY OF THE DETROIT RIVER 1975-1984

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FOREWORD

The Detroit River is identified as one of 42 Great Lakes Areas of Concern (IJC, 1985). Efforts to restore these areas to conditions suitable for desired uses have been initiated as part of the Remedial Action Plan Program (RAP) for areas of concern situated on the Connecting Channels and throughout the Great Lakes.

The Michigan Department of Natural Resources and the Ontario Ministry of the Environment (MOE) are taking lead roles in development of a Remedial Action Plan for the Detroit River. As part of the plan, public stakeholders are being solicited for their concerns regarding restoration of impaired uses. A large body of information relevant to historical and emerging water quality problems is being assimilated for the Detroit River through the 4 year bi-national Upper Great Lakes Connecting Channels Study (UGLCCS). A final report including identification of data gaps and recommendations for control is anticipated by early 1988.

Bacteriological contamination documented since 1975 (Kinkead & Hamdy, 1976) has been identified as the most significant water quality problem associated with the Ontario shoreline.

A number of corrective measures are being implemented to control bacterial contamination from point sources along the Windsor waterfront. Capital expenditures in excess of $145 million from 1964 to 1985 have involved construction and expansion of water pollution control plants (WPCP), sanitary and storm relief sewers and industrial waste control measures in the Windsor area (Harding and Faust, 1987). A further $145 million has been cited as necessary for future improvements and expansion.

Recent improvements to the Little River pollution control plant include pumping system upgrading to increase pumping capacity to 218,000 m^3/d. Projected expansion to accommodate local development includes the construction of two additional primary settling tanks.

The newly begun South Windsor sanitary sewer construction project is a 6 year $40 million plan funded equally by the City of Windsor and the Ontario Ministry of the Environment. This project will provide sanitary sewers to previously unserviced areas in West Windsor, Sandwich West and the City of Windsor which otherwise discharge septic material directly to Turkey Creek and the Grand Marais drain.

Improvements to the Amherstburg Water Pollution Control Plant during 1985 included installation of two new sewage pumps to increase primary capacity to 7,700 m^3/d, addition of a fine-screening hydro-sieve, a primary clarifier and a sludge belt press. Recently completed installation (1987) of a flap-gate to the final discharge pipe prevents backwashing of river water and reduces flow to within plant design levels (A. Stevens, personal communication).

This report describes spatial and temporal trends of bacteriological conditions along the Ontario shoreline of the Detroit River from 1975 to 1984. Recommendations for continued monitoring to implement remedial measures include: i) estimation of bacterial loadings under various control scenarios, ii) identification of bacterial sources through comparison of point/non-point inputs with in-stream loadings, and iii) identification of zones of high bacterial density and evaluate feasible hydraulic and pollution control alternatives.

A follow-up investigation in 1987 is underway to assess the effectiveness of remedial measures with emphasis on changes since 1984 and the identification of specific point sources.

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EXECUTIVE SUMMARY

Synopsis

An analysis of the bacteriological quality of the Canadian side of the Detroit River, including examination of trends and potential factors affecting water quality, was conducted using data collected by the Ontario Ministry of the Environment's Great Lakes Section between 1975 and 1984. Specific factors which were examined included point discharges into the river, distance from the Canadian shore, sampling station location along the shoreline, and variation with time. Statistical analyses were performed to determine the level of significance associated with various factors.

Key Findings

1. In general, the bacteriological quality of the Detroit River deteriorated between 1975 and 1984.

2. The Provincial Water Quality Objective for fecal coliforms (FC: 100 organisms/100 mL) was frequently exceeded in the Detroit River between 1975 and 1984. The frequency with which the FC objective was violated increased from 66.7% (10 of 15 stations) in 1975 to 86.7% (13 of 15 stations) in 1981. The number of stations at which the Provincial objective has been exceeded appears to have remained relatively constant at 12 of 14 and 13 of 15 stations (approximately 86-87%) since 1981. In addition, the frequency of violation increased with increasing distance downstream from Lake St. Clair for all years examined.

3. Analysis of fecal coliform densities upstream and downstream from each major input to the Detroit River (combined sewer overflows (CSOs), WPCPs and tributaries) showed that these inputs had a statistically significant impact on the bacteriological quality of the Detroit River. The change in fecal coliform density between the upstream and downstream stations for each input follows:

Input	Change in Bacterial Density
Little River	increase
City of Windsor CSOs	increase
West Windsor WPCP	decrease
Turkey Creek	increase
Amherstburg WPCP	increase

4. The highest FC levels coincided with the highest rainfall recorded during any given sampling season. However, the lowest FC levels coincided with the second highest rainfall. As a result, no definite conclusions regarding the impact of precipitation on Detroit River bacteriological quality could be made.

5. Fecal coliform densities generally decreased with increasing distance from shore, implying that the bacterial contamination along the Canadian nearshore is due to sources along the shoreline.

6. Based on results for samples collected during consecutive cruises in a given year, it appears that fecal coliform densities tend to increase as the summer progresses.

Recommendations for Further Study

Further study of the bacteriological contamination of the Detroit River is recommended, with emphasis on a comprehensive definition of the causes and effects of bacterial contamination within the river. In addition, development of a remedial action plan (RAP) for the Detroit River, with emphasis on the reach beginning upstream of Little River to the West Windsor WPCP, should be given priority.

Proposed objectives which should form the basis for the dual activities of continued monitoring and remedial measures planning are as follows:

1. To estimate in-stream and tributary bacterial loadings under current and projected future (no additional controls) conditions.

2. To compare in-stream loadings with loadings from known point sources and tributary inputs, to determine if all sources of bacterial contamination have been identified.

3. To identify areas along the Detroit River subject to relatively high bacterial densities, and to investigate possible hydraulic relief or pollution control alternatives.

4. To evaluate feasible hydraulic and pollutant control options on the basis of effectiveness and cost and incorporate these feasible alternatives into an implementation plan for the Detroit River study area.

Key items of a work plan for addressing the above-noted objectives are as follows:

Catchment Characterization

- Compile catchment data

- Develop a modelling approach specific to the tributary area and simulate runoff and CSO discharges to the River.

- Estimate flow quantities and bacterial loadings from tributaries discharging into the Detroit River.

- Estimate industrial flows and bacterial loadings discharged directly to the Detroit River or indirectly by way of tributaries.

Detroit River Characterization

- Compile data about the physical characteristics of the Detroit River on a reach-by-reach basis.

- Evaluate nearshore hydraulic behaviour of the River to determine the degree of advection and dispersion in both the longitudinal and lateral flow directions.

- Examine bacterial survival within the Detroit River to establish characteristic die-off phenomena.

- Build a model to simulate the behaviour of selected bacteriological parameters within the Detroit River.

Selection, Evaluation, and Formulation of Pollution Control Plan

- Identify a short list of feasible remedial measures to control quantity and/or quality of inputs to the Detroit River.

- Evaluate the feasibility and cost-effectiveness of the various control alternatives and develop a systemwide remedial strategy.

- Formulate an implementation plan which will provide a phased approach for developing the institutional and physical requirements for cost-effective pollution control.

SOMMAIRE

Introduction

On a effectué une analyse de la qualité bactériologique des eaux de la rivière Détroit du côté canadien, y compris une étude des tendances et des facteurs pouvant entraîner une dégradation de la qualité de l'eau; cette analyse a été réalisée à partir des données recueillies par la section des Grands Lacs du ministère de l'Environnement de l'Ontario entre 1975 et 1984. Elle a porté, entre autres, sur les points suivants : déversements ponctuels effectués dans la rivière, distance par rapport à la rive canadienne, situation de la station d'échantillonnage le long de la côte, et évolution dans le temps. On s'est livré à des analyses statistiques pour établir le degré d'importance de ces divers facteurs.

Principaux résultats

1. En général, la qualité bactériologique de l'eau de la rivière Détroit s'est détériorée entre 1975 et 1984.
2. Le seuil fixé par la province en ce qui concerne les concentrations de coliformes fécaux (100 organismes/100mL) a souvent été dépassé dans la rivière Détroit entre 1975 et 1984. La fréquence des cas de dépassement du seuil en question est passée de 66,7 p. 100 (10 stations sur 15) en 1975 à 86,7 p. 100 (13 stations sur 15) en 1981. Le nombre de stations où le seuil provincial a été dépassé est resté relativement stable depuis 1981, avec 12 stations sur 14 et 13 stations sur 15 (soit environ 86-87 p. 100). De plus, au cours des années où l'on a mené l'étude, la fréquence des cas de dépassement augmentait à mesure que l'on s'éloignait en aval du lac St. Clair.
3. En analysant les densités de coliformes fécaux enregistrées en amont et en aval de chacun des principaux points de déversement dans la rivière Détroit (déversoirs d'égouts unitaires (DEU), usines de dépollution de l'eau

(UDE), et affluents), on a constaté que ces déversements avaient, du point de vue statistique, une incidence importante sur la qualité bactériologique de l'eau de la rivière. La fluctuation de la densité de coliformes fécaux enregistrée à chacune des stations situées en amont et en aval a été la suivante :

Point de déversement	Fluctuation de la densité de bactéries
Little River	Augmentation
DEU de la ville de Windsor	Augmentation
UDE de Windsor West	Diminution
Turkey Creek	Augmentation
UDE d'Amherstburg	Augmentation

4. Quelle qu'ait été la saison où on effectuait les prélèvements, les concentrations de coliformes fécaux les plus élevées coïncidaient avec la précipitation la plus forte. Par contre, les concentrations de coliformes fécaux les plus faibles coïncidaient, quant à elles, avec la deuxième précipitation par ordre d'importance. En conséquence, on ne peut tirer de conclusions définitives en ce qui a trait à l'incidence des précipitations sur la qualité bactériologique de l'eau de la rivière Détroit.
5. Les concentrations de coliformes fécaux diminuent généralement à mesure que l'on s'éloigne de la rive, ce qui signifie que la contamination bactérienne enregistrée le long de la côte canadienne est due à des sources situées sur la rive.
6. Les résultats de prélèvements effectués au cours d'inspections consécutives durant toute une année montrent que les concentrations de coliformes fécaux tendent à augmenter pendant l'été.

Recommandations pour l'avenir

Il est recommandé de poursuivre les études sur la pollution bactériologique de la rivière Détroit et de chercher à définir en détail les causes et les effets de cette pollution. De plus, il conviendra d'accorder la priorité à l'élaboration d'un plan de mesures correctrices pour la rivière Détroit, et de mettre particulièrement l'accent sur le tronçon commençant en amont de Little River et finissant à l'UDE de Windsor West.

Pour la poursuite de la surveillance et la mise en oeuvre des mesures correctrices, on s'est proposé les objectifs suivants :

1. Évaluer les charges de bactéries déversées soit directement dans la rivière, soit par les affluents, dans l'état actuel des choses et compte tenu des conditions prévisibles (sans aucune réduction supplémentaire).
2. Comparer les charges déversées directement dans la rivière avec les charges provenant de sources ponctuelles ou apportées par les affluents, afin de savoir si l'on connaît toutes les sources de contamination bactérienne.
3. Déterminer les secteurs de la rivière Détroit où les concentrations de bactéries sont relativement élevées, et chercher de nouvelles solutions pour assainir l'eau ou réduire la pollution.
4. Évaluer les solutions en question du point de vue de leur efficacité et de leur coût, et les intégrer à un plan de mise en oeuvre portant sur le tronçon étudié de la rivière Détroit.

Les principaux points qu'il faudrait intégrer à un plan de travail pour atteindre les objectifs énoncés ci-dessus sont les suivants :

Captage

. Compiler des données sur le captage des eaux.

. Élaborer un modèle pour l'étude des eaux apportées par les affluents et faire des simulations sur les eaux de ruissellement et celles qui proviennent des déversoirs d'égouts unitaires.
. Évaluer les volumes d'eau et les charges de bactéries déversés par les affluents dans la rivière Détroit.
. Évaluer les volumes d'eau et les charges de bactéries déversés directement par les industries dans la rivière Détroit, ou indirectement par le biais des affluents.

Caractéristiques de la rivière Détroit

. Recueillir des données sur les caractéristiques physiques de la rivière Détroit, tronçon par tronçon.
. Étudier les caractéristiques hydrauliques de la rivière à proximité des rives afin d'établir le degré d'advection et de dispersion, dans les sens longitudinal et transversal.
. Étudier le taux de survie des bactéries dans la rivière Détroit afin d'établir le phénomène de dépérissement caractéristique.
. Élaborer un modèle afin de simuler le comportement de divers paramètres bactériologiques dans la rivière Détroit.

Sélection, évaluation et formulation d'un plan de dépollution

. Établir une courte liste de mesures correctrices à prendre pour surveiller le volume et la qualité des eaux déversées dans la rivière Détroit.
. Évaluer la faisabilité et la rentabilité des diverses méthodes de lutte envisagées, et élaborer une stratégie d'intervention valable pour tout le réseau.
. Formuler un plan de mise en oeuvre qui permette de définir progressivement les conditions à remplir en usine et les caractéristiques physiques à atteindre pour limiter la pollution de façon rentable.

1.0 INTRODUCTION AND OBJECTIVES

1.1 Background

The bacteriological quality of the Detroit River has been relatively poor since the late 1960's (IJC, 1968). Although efforts to improve water quality have been undertaken, the Great Lakes Water Quality Board (1985) identified the upper Great Lakes connecting channels, which includes the Detroit River, as areas of concern in 1985. In response to concerns about the quality of water in these connecting channels, officials from municipal, provincial, state, federal and international agencies are collaborating on the development of remedial action plans. The initial responsibility of the Detroit River RAP Committee has been to produce a concise statement for submission to the RAP Steering Committee in order to:

- Identify specific problems
- Provide guidelines for defining problems and impairment of beneficial uses
- Describe historical abatement measures
- Include suggestions for dealing with existing problems

Technical material used in development of the final RAP will be extracted from the report of the management committee for the bi-national Upper Great Lakes Connecting Channels Study (UGLCCS) scheduled for completion in early 1988.

The Ontario Ministry of the Environment has monitored bacterial levels at various locations along the Canadian side of the Detroit River since 1975, in an effort to determine trends in water quality and to establish locations along the river where remedial action is required.

1.2 Study Objectives

The purpose of this study was to analyze bacteriological data collected in the Detroit River between 1975 and 1984. As part of the analysis, the impact of various factors on observed bacterial densities was also examined. These factors included:

- Non-Point source tributary inputs
- Precipitation before and during sampling
- Distance from shore
- Monthly variation
- Year-to-year variation and trends

2.0 STUDY AREA

The study area is shown in Figure 1 and encompasses the Canadian side of the Detroit River, from upstream of the Little River downstream to Bar Point. A total of 15 stations have been consistently monitored by the MOE; these are identified in Figure 1 by the distance, in miles, from the mouth. The width of the Detroit River at each station is shown in Table 1.

Table 1
WIDTH OF DETROIT RIVER AT ONTARIO
MINISTRY OF THE ENVIRONMENT
BACTERIOLOGICAL MONITORING STATIONS

Station	Width (m)
DT 30.7e	335
DT 30.1e	396
DT 26.4e	610
DT 25.5	914
DT 23.1	701
DT 20.6	731
DT 20.1	793
DT 18.0	777
DT 17.0e	305
DT 9.8	1,951
DT 9.0	396
DT 8.2	351
DT 6.7e	381
DT 5.7	335
DT 3.9	6,096

Note: e = east

Figure 1 also shows known point sources and non-point source tributary inputs to the Detroit River; these include:

- Little River, including Little River WPCP
- City of Windsor CSOs
- West Windsor WPCP
- Turkey Creek
- Riviere aux Canards
- Amherstburg WPCP

The locations of a number of stations were chosen in proximity to the point sources. Table 2 lists applicable upstream and downstream stations associated with each point source.

Table 2
BACTERIOLOGICAL MONITORING STATIONS IN
PROXIMITY TO KNOWN POINT DISCHARGES

Point Source	Station	
	Upstream	Downstream
Little River	DT 30.7e	DT 30.1e
Windsor CSOs - 22 [1]	DT 26.4e	DT 20.6
West Windsor WPCP	DT 20.6	DT 20.1
Turkey Creek	DT 18.0	DT 17.0
Riviere aux Canards	N/A [2]	DT 9.8
Amherstburg WPCP	DT 6.7e	DT 5.7

NOTES: (1) Refers to the number of CSO outfalls between the 2 stations listed.

(2) There was no upstream station in close proximity to Riviere aux Canards

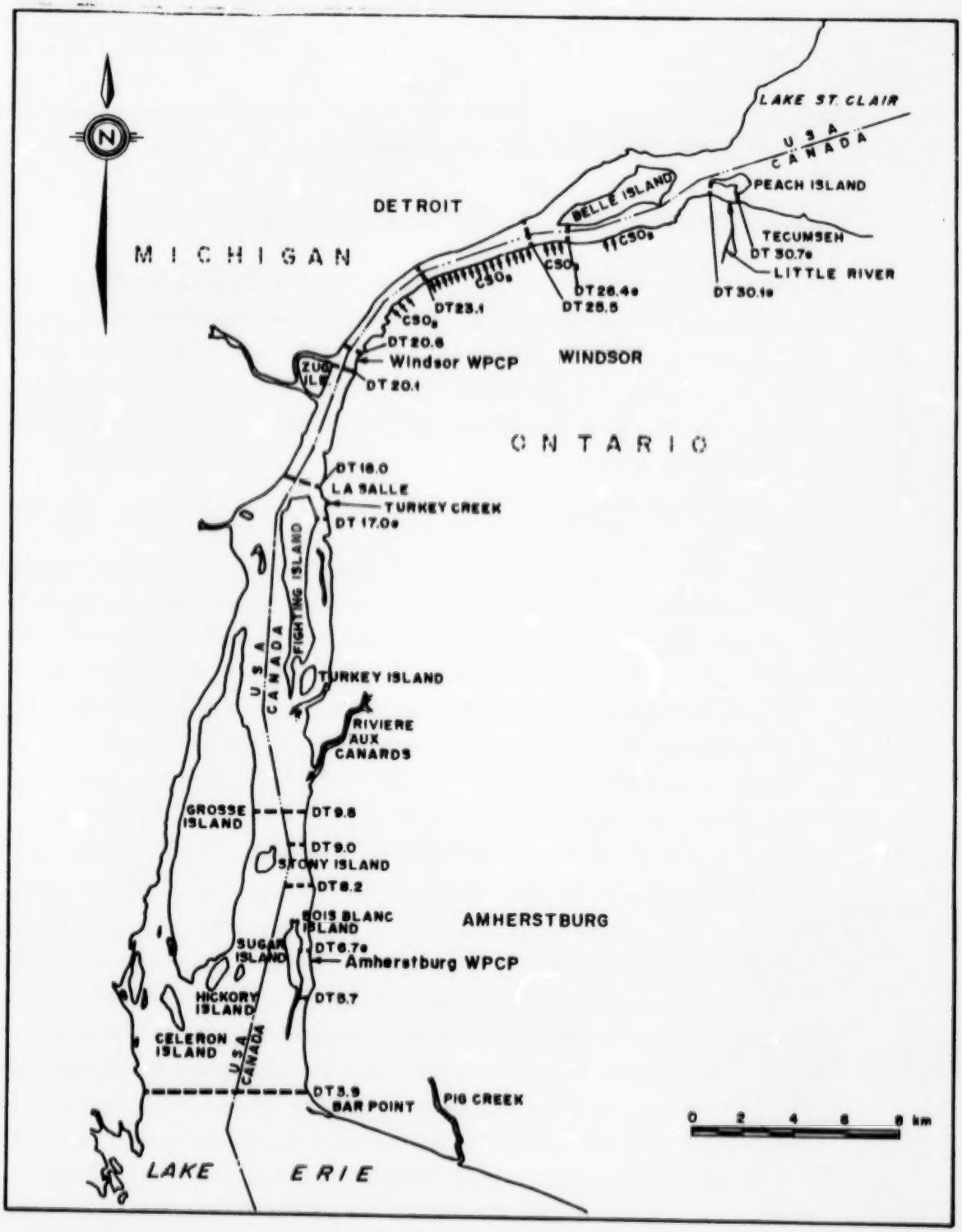

FIGURE 1. MAP OF DETROIT RIVER FROM LAKE ST. CLAIR TO LAKE ERIE SHOWING ONTARIO MINISTRY OF THE ENVIRONMENT BACTERIOLOGICAL MONITORING STATIONS AND KNOWN POINT DISCHARGES

3.0 PAST AND PROJECTED REMEDIAL MEASURES

3.1 Chronology of Existing Water Pollution Control Measures

A number of corrective measures have been implemented to control bacterial contamination from point sources along the Windsor waterfront. Capital expenditures in excess of $145 million from 1964 to 1985 have involved construction and expansion of water pollution control plants, sanitary and storm relief sewers and industrial waste control measures in the Windsor area.

Little River

The Little River is the first major flow input to the Detroit River downstream from Lake St. Clair. The mean daily discharge rate in 1984 was 37,066 m^3/d. Possible sources of bacterial pollution reaching the Little River include dry weather seepage from storm sewer outlets, and stormwater runoff from both urban and non-urban areas. Bypass and effluent from the Windsor Little River WPCP also contribute bacterial loads to the Little River. The Little River WPCP was constructed in 1965 at a cost of $4.5 million (1965 $). At that time it was designed for a population of 50,000, and had a design capacity of 18,000 m^3/d. The plant treated sewage by the conventional activated sludge process. In 1973, the capacity of the Little River WPCP was increased to 36,000 m^3/d. The expansion allowed for treatment of wastewaters from the eastern part of Windsor, the Town of Tecumseh, Village of St. Clair Beach, and Sandwich South Township. Phosphorus removal facilities were also implemented with the expansion. In 1982, a second expansion at the Little River WPCP was initiated to increase the capacity of the plant from 36,000 m^3/d to 64,000 m^3/d. Disinfection at the plant, which treats about 33,000 m^3/d (MOE, 1983), is practiced seasonally from May to October.

A chronology of pollution control measures and associated costs for the Little River WPCP in the period 1965-1985 follows:

Year	Description	Amount
1965	Water Pollution Control Plant designed for 50,000 people, design flow 18,000 m^3/day. Wastewater treatment consists of primary and conventional activated sludge processes including chlorination for disinfecting treated wastewater.	$ 4,500,000
1966-68	Little River Drainage Basin - Phases I and II	$ 2,000,000
1966-70	Clairview Pumping Station and Sandwich East Sanitary Trunk Sewer	$ 1,100,000
1971-73	Little River WPCP expansion from 18,000 m^3/day to 36,000 m^3/day. Expanded plant provides sewage treatment for eastern area of Windsor, Town of Tecumseh, Village of St. Clair Beach and Sandwich South Township. A process for phosphorus removal was incorporated in this expansion.	$ 4,500,000
1982-85	Little River WPCP expansion. Flow to existing plant excessive of plant's capacity. Preliminary design for another plant expansion from 36,000 m^3/day to 64,000 m^3/day commenced in 1982. Total expended to end of 1985.	$ 1,100,000
	TOTAL	$13,200,000

Source: Harding and Faust, 1987.

More recent improvements to the Little River pollution control plant include pumping system upgrading to increase pumping capacity to 218,000 m^3/d. Projected expansion to accommodate local development includes the construction of two additional primary settling tanks. (A. Stevens, Pers. Comm.)

City of Windsor CSOs

In the recently-completed City of Windsor pollution control plan feasibility study, combined sewer overflows were identified as a significant contributor to the overall pollution problem within the City (LaFontaine, Cowie, Buratto and Assoc. Ltd. 1986). Combined sewer overflows are likely the predominant source of wet weather bacterial discharge to the Detroit River in the reach between the Little River confluence and the West Windsor WPCP. A total of 24 CSO outfalls are located in this reach. All flows in excess of 2.5 times the dry weather flow (DWF) capacity of the Windsor Riverfront Interceptor are diverted directly to the river (LaFontaine, Cowie, Buratto and Assoc. Ltd., 1986). The CSO outfalls may also contribute bacterial inputs in dry weather through seepage and possible dry weather overflows; although, it should be noted that there is no evidence to support the latter possibility.

A chronology of storm water management pollution control measures implemented in the period 1970 to 1985 follows:

Year	Description	Amount
1970-78	Grand Marais Drain Improvement	$ 6,290,000
1971-74	St. Paul Storm Water Pumping Station	4,600,000
1974-77	St. Paul Relief Sewers	2,600,000
1972	George Avenue Storm Relief Sewer	1,600,000
1973	Little River Channel Improvements	600,000
1973	Alexander Park Seawall Construction	160,000
1975-76	Jerome Storm Water Pumping Station	2,800,000
1977-81	Parent/McDougall Storm Relief Sewers	3,450,000
1978-79	Northway Storm Water Trunk Sewer	2,230,000
1979-83	Various Storm Relief Systems	5,300,000
1984-85	Various Storm Relief Systems	7,200,000
	TOTAL	$36,830,000

Source: Harding and Faust, 1987.

The newly begun South Windsor sanitary sewer construction project is a 6 year $40 million plan funded equally by the City of Windsor and the Ontario Ministry of the Environment. This project will provide sanitary sewers to previously unserviced areas in West Windsor, Sandwich West and the City of Windsor which otherwise discharge septic material directly to Turkey Creek and the Grand Marais drain (A. Stevens, Pers. Comm.).

West Windsor WPCP

The West Windsor WPCP, located downstream of the City of Windsor CSOs, is the next major flow input to the Detroit River. The West Windsor WPCP was brought on-line in 1969 at a cost of $9 million (1969 $) and was initially designed to treat up to 108,000 m^3/d. In 1973, phosphorus removal capability was implemented at the plant. The hydraulic capacity of the West Windsor WPCP was increased to 163,000 m^3/d in 1980, and was undertaken in order to provide treatment of wastewaters from recently serviced areas in South Windsor, as well as areas in Sandwich West. The plant provides physical-chemical treatment including chlorination, which is practiced seasonally from May 1 to November 1. The plant currently receives average daily flows of 105,000 m^3/d (MOE, 1983).

A chronology of remedial measures implemented in the period 1964-1985 follows:

Year	Description	Amount
1964-69	Riverfront Interceptor Sewer	$ 5,000,000
1965-69	West Windsor WPCP	9,000,000
1969	Western Main Trunk Sewer	3,300,000
1969	South Street Sanitary Sewer Construction and Chambers	400,000
1970-81	Grand Marais Trunk Sewer	8,100,000
1982-84	Lennon Trunk Sewer	1,900,000
1971-73	Sub-Trunk Sewers	1,400,000
1972-73	West Windsor WPCP - Addition of Facilities for Phosphorus Removal	1,000,000
1975-80	Expansion - Hydraulic Capacity. Increased from 108,000 m^3/day to 163,000 m^3/day. Expanded plant to provide sewage treatment for areas in South Windsor recently serviced with sanitary sewers, as well as areas in the adjacent municipality of Sandwich West	16,000,000
1972-83	Local Improvements - Sanitary Sewers	16,200,000
1984-85	Local Improvements - Sanitary Sewers	3,000,000
	TOTAL	$65,300,000

Source: Harding and Faust, 1987.

Turkey Creek

Turkey Creek, which is located downstream from the West Windsor WPCP, discharges approximately 29,000 m^3/d on average into the Detroit River (Environment Canada, 1985). Turkey Creek receives stormwater runoff and other effluents which have contributed to the degradation of the watercourse (LaFontaine, Cowie, Buratto and Assoc. Ltd., 1986). The Grand Marais, Cahill, and Lennon Drains all contribute flows to Turkey Creek. In addition to dry weather seepage and stormwater runoff, these drains also receive septic tank overflows on a fairly continuous basis.

Riviere aux Canards

Riviere aux Canards contributes on average, in excess of 131,000 m^3/d of flow to the Detroit River (Environment Canada, 1985). Potential bacterial sources to Riviere aux Canards are primarily dry weather seepage and stormwater runoff.

Amherstburg WPCP

The Amherstburg WPCP, which serves the Town of Amherstburg, and the Township of Anderdon and Malden, is a primary treatment plant with phosphorus removal facilities. Chlorination of plant effluent is practiced from May 15 to October 15. The plant has a design capacity of 4,550 m^3/d and currently treats almost 5,000 m^3/d (MOE, 1983). Historically, the plant has discharged effluent containing high fecal coliform levels (Kinkead and Hamdy, 1976).

Improvements to the Amherstburg Water Pollution Control Plant during 1985 included installation of two new sewage pumps to increase primary capacity to 7700 m^3/d; addition of a fine-screening hydro-sieve; a primary clarifier and a sludge belt press. Recently completed installation (1987) of a flap-gate to the final discharge pipe prevents backwashing of river water and reduces flow to within plant design levels (A. Stevens, Pers. Comm.).

Industrial Pollution Control Measures

Automotive, metal fabricating, machinery design and building, food and beverage industries, plastic parts manufacturing and service industries form the basis of the Windsor economy.

Windsor's industrial pollution control program was initiated in 1969 through the enactment of a Sewer-Use By-law, recruitment of technical staff, provision of suitable laboratory facilities and the necessary amenities for sampling and monitoring industrial discharges.

While the industrial base is broadly diversified, the main problems with respect to industrial waste control involved neutralization of acids and alkalis, pre-treatment of electroplating wastewater for removal of heavy metals and pre-treatment of oily wastewater for removal of oil and grease.

In the interim period, abatement facilities have been designed, constructed and placed into operation at all plants where necessary. The total capital expenditure for these facilities amounts to in excess of $30 million. The city of Windsor monitors the industrial discharges on an ongoing basis for the enforcement of the city's Sewer-Use By-Law.

3.2 Projected Water Pollution Control Measures

Water pollution control problems in Windsor include basement flooding, sewage treatment plant bypasses, bacterial contamination of watercourses and combined sewer overflows.

The City of Windsor (Harding and Faust, 1987) has projected expenditures in the order of $145 million to provide for further corrective measures. These measures will include construction of an improved sanitary and storm relief sewer network and increased capacity at the Little River Water Pollution Control Plant.

4.0 MONITORING PROGRAM

The Ontario Ministry of the Environment initiated bacteriological monitoring in the Detroit River in 1975 in order to assess changes in water quality resulting from increased control of untreated or inadequately treated sanitary wastes (Kinkead and Hamdy, 1976). The first monitoring period consisted of three cruises to collect samples at 19 stations. In subsequent years, monitoring periods have consisted of two cruises, and sample locations have been reduced to 15 stations.

Typically, cruises occurred during spring/early summer and again in mid/late summer. Each cruise required from 3 to 6 days to complete. Three samples were usually taken per cruise-day at each station at nominal distances of 15 m, 60 m and 180 m from the Canadian shore. Table 3 shows the dates of the monitoring cruises.

Table 3
DETROIT RIVER BACTERIOLOGICAL MONITORING
CRUISE DATES

Year	Cruise	Sampling Dates
1975	1 2 3	May 6 - 10 July 14 - 18 August 15 - 20
1978	1 2	June 26 - 29 July 25 - 28
1981	1 2	May 30 - June 1 July 28 - 30
1982	1 2	July 19 - 21 August 16 - 18
1984	1 2	June 19 - 21 August 27 - 29

5.0 PRESENTATION OF MONITORING RESULTS AND TRENDS IN YEARLY BACTERIAL QUALITY

5.1 Summary of Results

Data for fecal coliform and fecal Streptococcus are contained in the Ontario Ministry of the Environment Sample Information System Database (MOE, 1986). It should be noted that a very limited amount of Pseudomonas aeruginosa data were collected between 1975 and 1984 as part of the monitoring program. Therefore, due to the limited data this parameter was not included in the analysis.

Table 4 presents geometric mean fecal coliform (FC) and fecal Streptococcus (FS) densities at distances of 15 m and 60 m from the Canadian shore for each station during 1975, 1978, 1981, 1982, and 1984. Confidence Limits for the 95% significance level are also provided in Table 4.

In general, the bacteriological quality of the Detroit River, in terms of fecal coliforms, tends to deteriorate with distance, with lower FC densities at the upstream stations and higher FC densities at the downstream stations. In addition, fecal coliform densities appear to be consistently higher than fecal Streptococcus densities. Bacterial densities appear to vary somewhat from year-to-year and by station location. Geometric mean FC and FS densities were highest in 1981. Fecal coliform densities for 1978 were generally lower than other years, while the lowest FS densities were recorded in 1975.

The minimum geometric mean FC and FS densities at stations 15 m from the Canadian shore were 7 and 4 organisms per 100 mL, respectively, which were recorded at DT 30.7e in 1978 for FC and at DT 20.1 in 1975 for FS. Corresponding maximum FC and FS densities shown in Table 4 were 1,026 and 980 org/100 mL, both of which were recorded at DT 9.8 in 1981. At 60 m from the Canadian shore, minimum FC and FS densities were 4 (DT 30.7e in 1978) and 5 (DT 30.7e in 1982) org/100 mL and maximum FC and FS densities were 669 and 380 org/100 mL, observed at DT 5.7 in 1984 and 1981, respectively.

Table 4 (a)
GEOMETRIC MEAN FECAL COLIFORM DENSITIES
OBSERVED AT 15 M, 60 M AND 180 M FROM THE CANADIAN SHORE FOR 1975 TO 1984 [1]

Station	Distance from Canadian Shore (m)	Fecal Coliform Density (org/100 mL)									
		1975		1978		1981		1982		1984	
		GM [4]	CL [5]	GM	CL	GM	CL	GM	CL	GM	CL
DT 30.7e	15	12	7.34	7	4.52	100	16.77	12	4.61	< 8	11.13
	60	- [2]	-	4	4.63	81	24.50	5	6.17	< 6	9.48
	180	5	6.27	4	4.80	-	-	-	-	-	-
DT 30.1e	15	45	8.68	21	10.25	376	26.06	86	8.45	50	15.91
	60	24	9.31	6	6.04	346	59.85	34	6.40	97	14.15
	180	7	8.64	5	3.65	-	-	-	-	-	-
DT 26.4e	15	154	11.03	51	7.42	95	17.98	114	12.37	177	5.09
	60	37	23.27	15	9.07	124	33.70	67	10.44	<38	8.53
	180	20	10.83	6	3.53	-	-	-	-	-	-
DT 25.5	15	100	9.53	37	24.29	200	11.01	211	7.06	108	6.05
	60	37	10.48	22	7.08	137	18.39	90	5.40	69	5.76
	180	20	13.84	8	4.00	-	-	-	-	-	-
DT 23.1	15	649	32.01	222	4.44	275	4.19	475	3.81	412	5.21
	60	274	52.01	27	9.31	274	3.76	176	3.16	397	3.44
	180	10	7.57	8	4.32	-	-	-	-	-	-
DT 20.6	15	237	5.37	199	4.47	308	4.09	453	4.64	487	5.02
	60	274	14.36	39	11.03	240	8.26	262	3.71	421	4.42
	180	100	25.63	16	8.83	-	-	-	-	-	-
DT 20.1	15	42	19.64	62	17.96	410	5.54	438	4.99	530	7.00
	60	221	11.48	30	10.26	306	3.60	291	3.70	495	4.40
	180	100	13.34	14	7.62	-	-	-	-	-	-
DT 18.0	15	133	8.96	110	4.28	319	8.59	432	7.66	343	4.49
	60	178	5.00	54	6.97	388	8.88	388	5.29	266	8.09
	180	75	18.67	19	8.53	-	-	-	-	-	-
DT 17.0e	15	220	6.29	141	6.29	413	4.27	392	6.51	389	3.67
	60	115	19.59	83	5.78	410	7.04	346	4.62	358	5.59
	180	133	5.21	44	5.92	-	-	138	4.82	-	-
DT 9.8	15	135	5.94	107	13.23	1,026	15.11	309	34.14	189	6.49
	60	153	12.27	76	5.76	243	12.02	264	15.47	161	8.03
	180	205	19.80	17	10.88	277	7.75	87	5.64	234	5.90

Table 4 (a) cont'd

Station	Distance from Canadian Shore (m)	Fecal Coliform Density (org/100 mL)									
		1975		1978		1981		1982		1984	
		GM [4]	CL [5]	GM	CL	GM	CL	GM	CL	GM	CL
DT 9.0	15	100	5.94	58	6.49	216	7.38	171	9.46	227	3.42
	60	153	9.57	20	10.57	238	12.26	221	8.81	229	3.85
	180	154	13.32	26	7.44	255	9.48	132	7.76	167	4.19
DT 8.2	15	154	6.06	33	8.83	283	6.33	232	9.03	244	4.53
	60	143	8.65	47	7.19	275	7.44	256	8.31	261	3.63
	180	143	13.28	39	9.14	234	10.11	24	15.00	143	3.65
DT 6.7e	15	191	4.86	42	6.68	342	7.66	242	8.45	261	22.57
	60	115	15.30	29	10.75	238	6.70	242	9.79	270	19.22
	180	205	4.02	49	7.37	166	5.55	100	9.11	223	-
DT 5.7	15	316	19.60	281	4.59	568	4.78	260	19.36	861	5.43
	60	64	10.65	36	15.01	404	5.95	120	8.34	669	14.61
	180	205	13.82	43	9.12	238	7.66	119	10.41	236	12.84
DT 3.9	30	205	-	256	-	534	5.54	469	3.18	-	-
	180	115	-	576	-	491	9.75	-	-	-	-
Minimum	@ 15 m	12		7		95		12		< 8	
	@ 60 m	24		4		81		5		< 6	
	@ 180 m	5		4		166		24		143	
Maximum	@ 15 m	649		281		1,026		475		861	
	@ 60 m	274		83		410		388		669	
	@ 180 m	205		49		576		491		236	

NOTES: (1) Data shown for 1975 to 1982 obtained from Hamdy (1986); data shown for 1984 represents the geometric mean of spring and summer means
(2) - indicates no value calculated/no data available
(3) Including sample taken @ 30 m (DT 3.9) along with samples taken @ 15 m
(4) Geometric mean
(5) ± 95% confidence limit

Table 4 (b)

GEOMETRIC MEAN FECAL STREPTOCOCCUS DENSITIES

OBSERVED AT 15 M, 60 M AND 180 M FROM THE CANADIAN SHORE FOR 1975 TO 1984 [1]

Station	Distance from Canadian Shore (m)	Fecal Streptococcus Density (org/100 mL)									
		1975		1978		1981		1982		1984	
		GM [4]	CL [5]	GM	CL	GM	CL	GM	CL	GM	CL
DT 30.7e	15	12	8.98	57	16.93	102	18.07	9	4.46	<8	9.43
	60	-	-	14	13.24	93	15.57	5	3.19	7	13.50
	180	4	6.51	5	2.52	-	-	-	-	-	-
DT 30.1e	15	22	14.34	70	18.54	244	36.77	24	7.44	19	7.00
	60	48	26.46	25	7.67	179	63.49	10	5.00	19	8.10
	180	1	5.67	5	2.58	-	-	-	-	-	-
DT 26.4e	15	22	14.25	134	13.76	37	8.54	25	8.47	26	7.79
	60	20	17.08	47	17.81	47	18.94	10	4.50	7	5.13
	180	6	10.61	27	11.42	-	-	-	-	-	-
DT 25.5	15	45	10.54	110	11.56	72	13.16	29	9.78	21	4.21
	60	12	9.58	84	15.95	52	14.15	15	8.19	8	4.43
	180	6	6.85	45	14.47	-	-	-	-	-	-
DT 23.1	15	87	5.32	205	6.84	60	5.93	42	3.77	48	4.80
	60	50	35.84	91	10.24	62	8.95	15	5.00	22	5.07
	180	4	7.09	24	10.68	-	-	-	-	-	-
DT 20.6	15	37	4.41	74	7.68	77	7.09	41	4.05	61	3.79
	60	22	8.57	55	9.62	127	14.45	28	5.21	47	5.95
	180	7	9.02	53	15.82	-	-	-	-	-	-
DT 20.1	15	4	10.44	21	9.79	69	7.19	40	6.76	48	4.17
	60	32	10.23	48	14.59	39	7.22	16	3.88	41	4.97
	180	12	6.59	37	17.65	-	-	-	-	-	-
DT 18.0	15	20	6.31	40	10.33	163	13.33	61	7.80	75	5.70
	60	10	6.89	19	12.81	48	13.98	25	5.01	47	7.71
	180	6	6.33	17	11.16	-	-	-	-	-	-
DT 17.0e	15	20	6.62	38	9.66	166	9.50	44	22.69	85	6.68
	60	24	4.51	16	8.51	95	11.96	27	18.36	50	9.64
	180	12	6.73	30	10.06	-	-	8	-	-	-
DT 9.8	15	20	10.80	39	7.83	980	60.59	18	6.89	27	10.54
	60	20	7.43	53	9.49	292	24.32	28	16.00	35	9.64
	180	20	10.43	15	11.95	107	9.22	8	4.43	43	11.42

Table 4 (b) cont'd

Station	Distance From Canadian Shore (m)	Fecal Streptococcus Density (org/100 mL)									
		1975		1978		1981		1982		1984	
		GM [4]	CL [5]	GM	CL	GM	CL	GM	CL	GM	CL
DT 9.0	15	20	11.28	25	11.60	88	12.87	63	11.38	39	12.63
	60	13	4.63	21	6.91	81	9.16	11	4.22	32	7.31
	180	7	5.64	11	9.93	76	13.89	18	12.68	25	8.85
DT 8.2	15	20	8.75	44	6.61	540	40.12	45	13.13	37	7.39
	60	20	5.97	18	8.96	232	23.80	31	9.80	32	7.66
	180	20	13.01	16	5.77	60	15.87	6	4.53	20	5.70
DT 6.7e	15	20	4.05	11	11.62	508	21.67	52	13.24	44	15.90
	60	12	7.07	15	7.71	346	30.49	49	19.77	31	29.26
	180	20	12.04	29	9.90	78	11.96	8	13.88	27	-
DT 5.7	15	39	6.73	55	8.94	573	28.32	53	8.61	96	5.29
	60	20	7.15	41	11.88	380	17.45	38	10.78	36	22.06
	180	12	5.47	27	9.82	250	29.66	38	12.01	13	4.23
DT 3.9	30	20	-	17	-	467	21.24	101	7.35	-	-
	180	18	-	506	-	33	37.53	-	7.78	-	..
Minimum	@ 15 m	4		11		37		9		8	
	@ 60 m	10		14		39		5		7	
	@ 180 m	1		5		60		6		13	
Maximum	@ 15 m	87		205		980		101 [3]		96	
	@ 60 m	50		91		380		49		50	
	@ 180 m	20		53		506		38		43	

NOTES: (1) Data shown for 1975 to 1982 obtained from Hamdy (1986); data shown for 1984 represents the geometric mean of spring and summer means
(2) - indicates no value calculated/no data available
(3) Including sample taken @ 30 m (DT 3.9) along with samples taken @ 15 m
(4) Geometric mean
(5) ± 95% confidence limit

5.2 Comparison of River Bacteriological Quality with Provincial Water Quality Objectives

Table 5 presents a summary of the frequency with which the Provincial fecal coliform objective of 100 organisms/100 mL for swimming and bathing use of water (MOE, 1984) has been exceeded.

Table 5
FREQUENCY OF VIOLATION OF PROVINCIAL WATER QUALITY OBJECTIVE FOR FECAL COLIFORMS

Parameter	Exceedance Frequency (%)	Major Point/Non-Point Source
Annual Violations [1]		
1975	66.7	
1978	46.7	
1981	86.7	
1982	86.7	
1984	85.7	
Station Violations [2]		
DT 30.7e	0.0	Little River
DT 30.1e	20.0	
DT 26.4e	60.0	
DT 25.5	80.0	City of Windsor CSOs
DT 23.1	100.0	
DT 20.6	100.0	
DT 20.1	60.0	West Windsor WPCP
DT 18.0	100.0	Turkey Creek
DT 17.0e	100.0	
DT 9.8	100.0	Riviere aux Canards
DT 9.0	80.0	
DT 8.2	80.0	
DT 6.7e	80.0	Amherstburg WPCP
DT 5.7	100.0	
DT 3.9	100.0	

Notes: (1) Calculated on the basis of geometric mean FC densities (@ 15 m offshore) for all data collected at 15 stations in a given year.

(2) Calculated on the basis of geometric mean FC densities (at 15 m offshore) for 5 years collected at a given station; note that for DT 3.9, the exceedance frequency is based on 4 years.

The frequency with which the Provincial objective was violated increased from 66.7% (10 of 15 stations) in 1975 to 86.7% (13 of 15 stations) in 1981. The number of stations at which the Provincial objective has been exceeded appears to have remained relatively constant at 12 of 14 or 13 of 15 (approximately 86-87%) since 1981.

The frequency with which the PWQO of 100 FC/100 mL was exceeded at each station (at 15 m from shore) was also calculated. At the most upstream station, DT 30.7e, the objective was not exceeded; however, at the downstream stations, which are located just north of the mouth, DT 5.7 and DT 3.9, the Provincial objective was consistently exceeded each year during which sampling was undertaken. The fact that the PWQO was not violated at upstream stations. (DT 30.7e), but was frequently exceeded at downstream stations further illustrates the decrease in river water bacteriological quality with increasing distance downstream.

5.3 Annual Variation in Bacterial Densities

Figures 2 through 6 present geometric mean fecal coliform levels (@ 15 m offshore) for each cruise conducted during 1975 through 1984, respectively. Examination of the graphed data indicates that, in general, bacteriological water quality deteriorated between 1975 and 1984. As shown in Figure 2, which presents data collected during 1975, the maximum fecal coliform density was almost 700 org/100 mL while FC levels at most stations were less than 200 org/100 mL. Data for 1978 (see Figure 3) indicates that, again, FC levels were generally less than 200 org/100 mL for most stations. Fecal coliform densities appeared to increase in 1981, relative to 1975 and 1978, as shown in Figure 4. With the exception of samples collected at the stations upstream from DT 23.1 during the June cruise, FC levels at all stations were greater than 100 org/100 mL for both cruises. FC levels for 1982, which are shown in Figure 5, appear to be somewhat lower than those for 1981, but were, in general, higher than either 1975 or 1978. Data collected in 1984 shows increased fecal coliform levels (see Figure 6), in comparison to other years.

Figure 7 illustrates geometric mean fecal coliform densities observed 15 m offshore for 1975 and 1984. In order to determine if changes in bacteriological water quality from 1975 to 1984 were significant, statistical analyses (Student's t-Tests on geometric mean fecal coliform densities at 15 m offshore for consecutive stations) on geometric mean fecal coliform levels were undertaken on a station by station basis; Table 6 presents the results of this analysis.

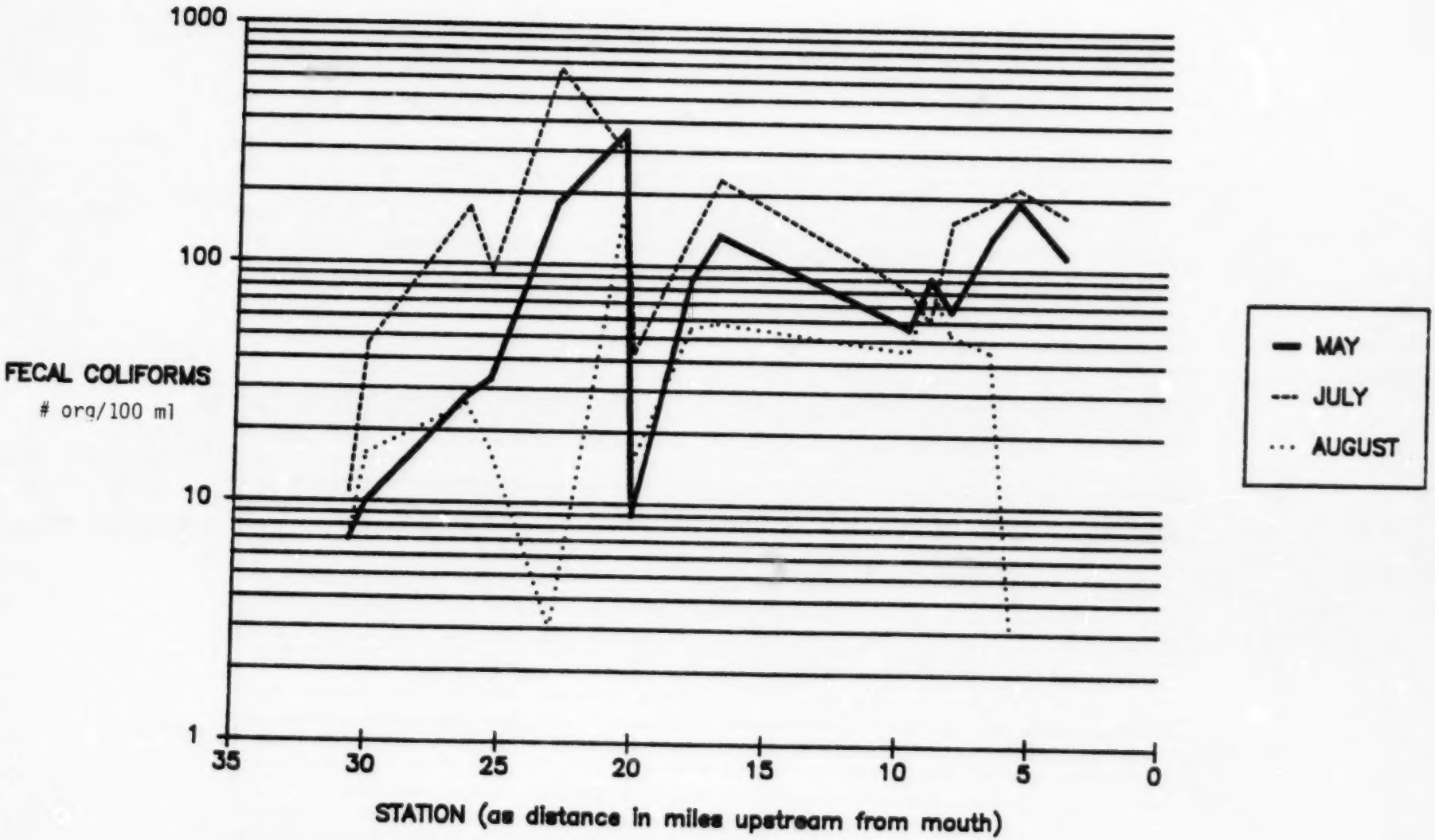

FIGURE 2. GEOMETRIC MEAN FECAL COLIFORM LEVELS 15 m OFFSHORE OBSERVED DURING MAY 6-10, JULY 14-18 AND AUGUST 15-20, 1975 cruises

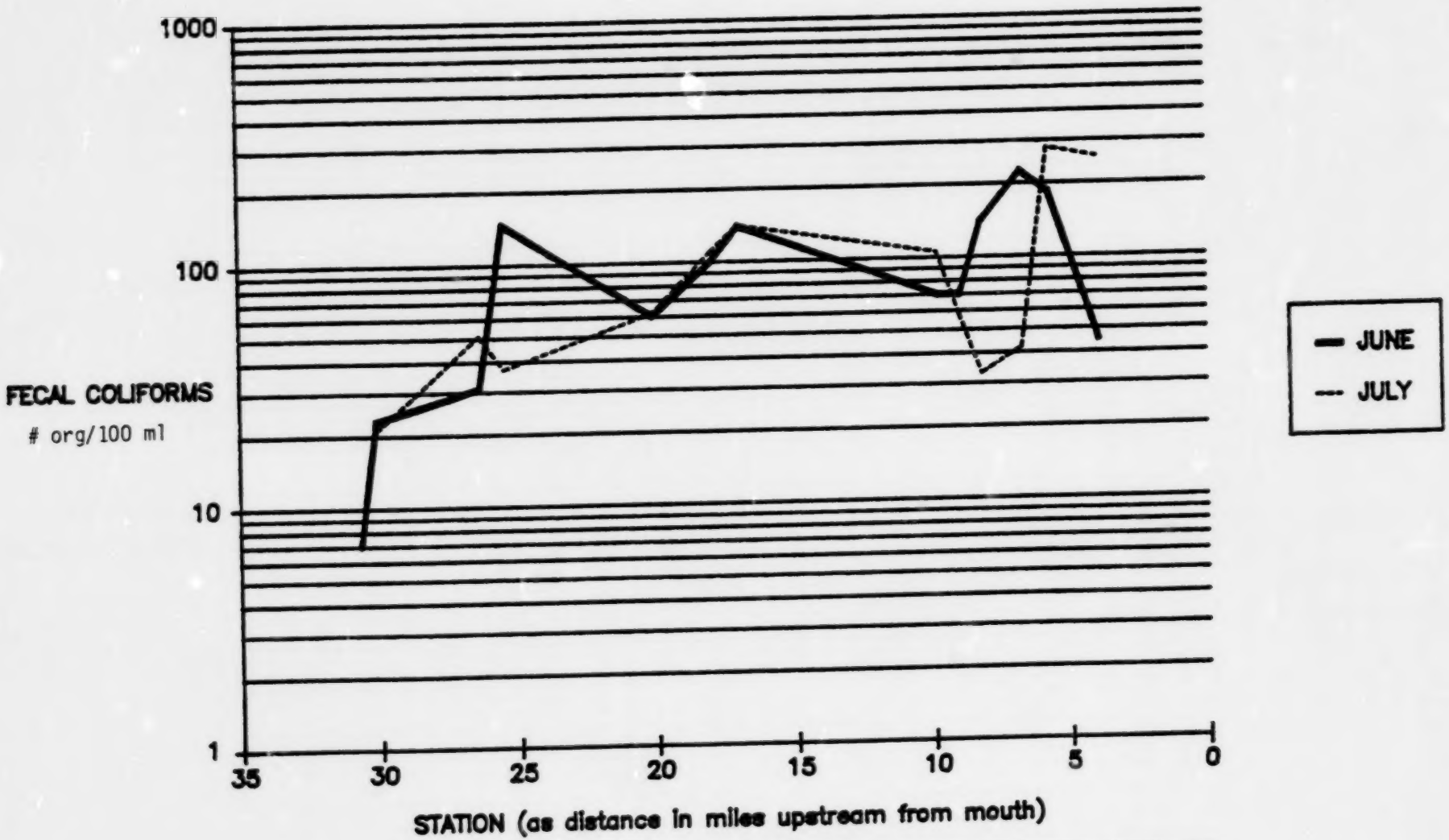

FIGURE 3. GEOMETRIC MEAN FECAL COLIFORM LEVELS 15 m OFFSHORE OBSERVED DURING JUNE 26-29, AND JULY 25-28, 1978 cruises

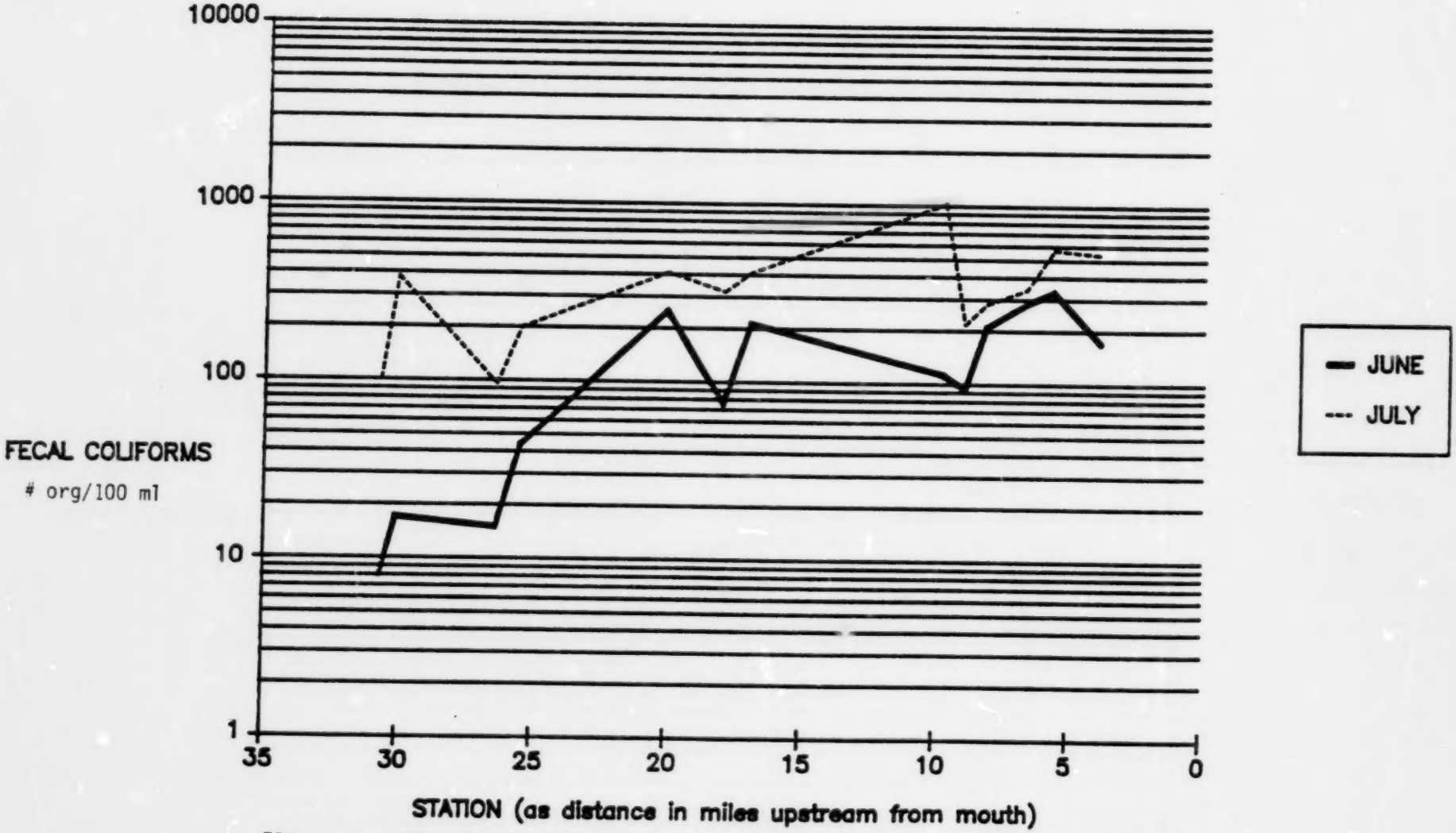

FIGURE 4. GEOMETRIC MEAN FECAL COLIFORM LEVELS 15 m OFFSHORE OBSERVED DURING MAY 30-JUNE 1 AND, JULY 28-30, 1981 cruises

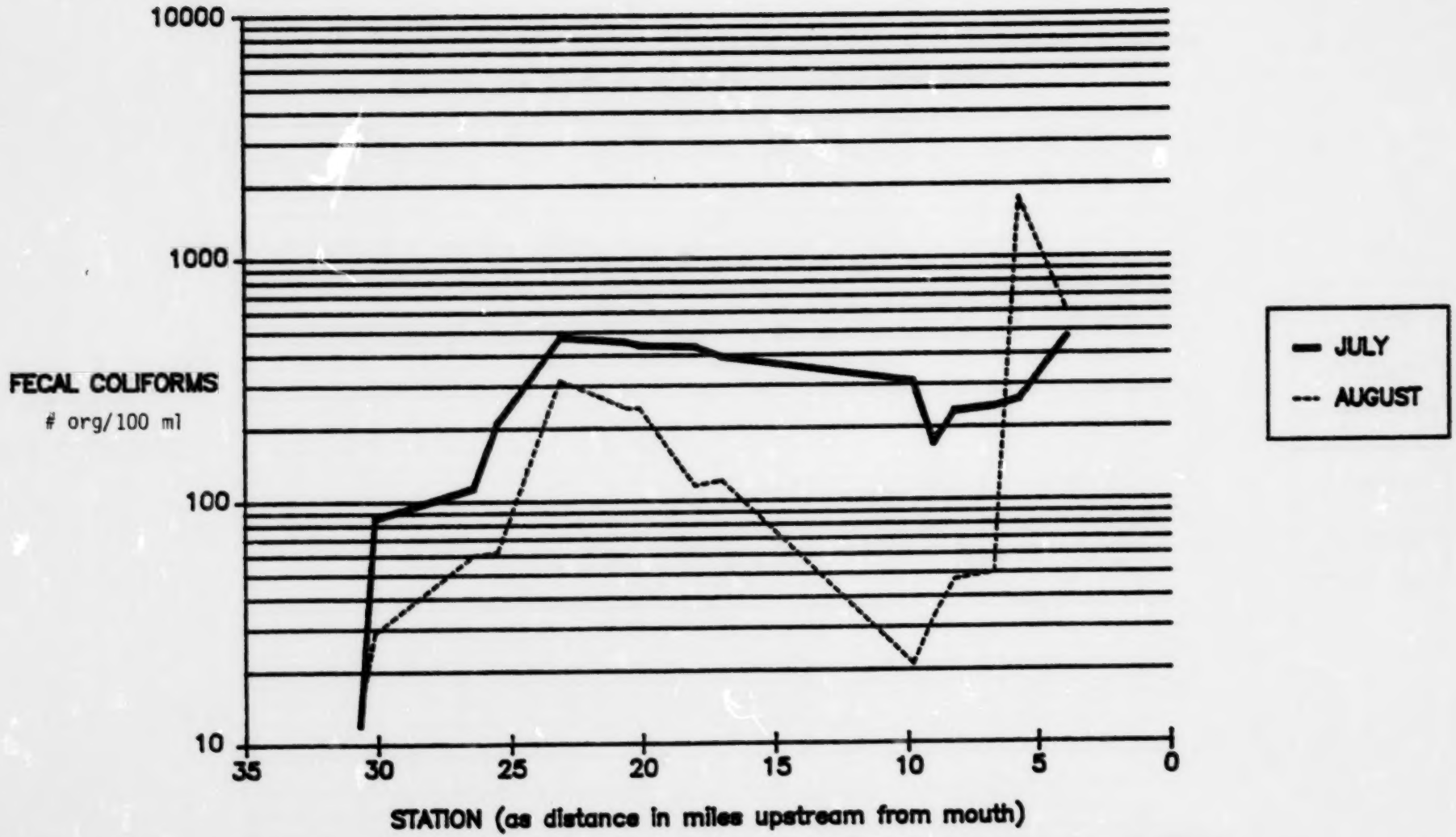

FIGURE 5. GEOMETRIC MEAN FECAL COLIFORM LEVELS 15 m OFFSHORE OBSERVED DURING JULY 19-21 AND AUGUST 16-18, 1982 cruises

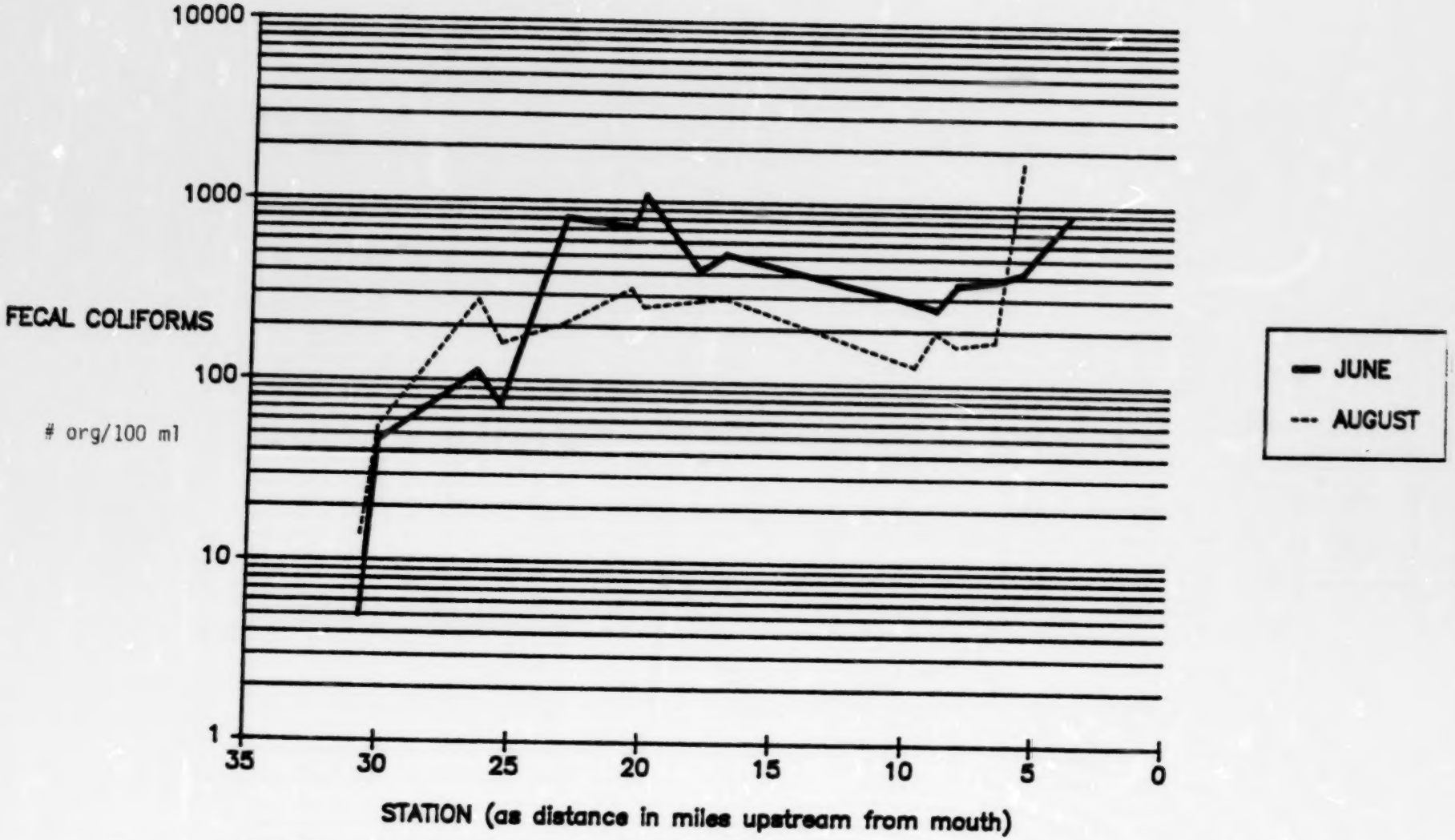

FIGURE 6. GEOMETRIC MEAN FECAL COLIFORM LEVELS 15 m OFFSHORE OBSERVED DURING JUNE 19-21 AND AUGUST 27-29, 1984 cruises

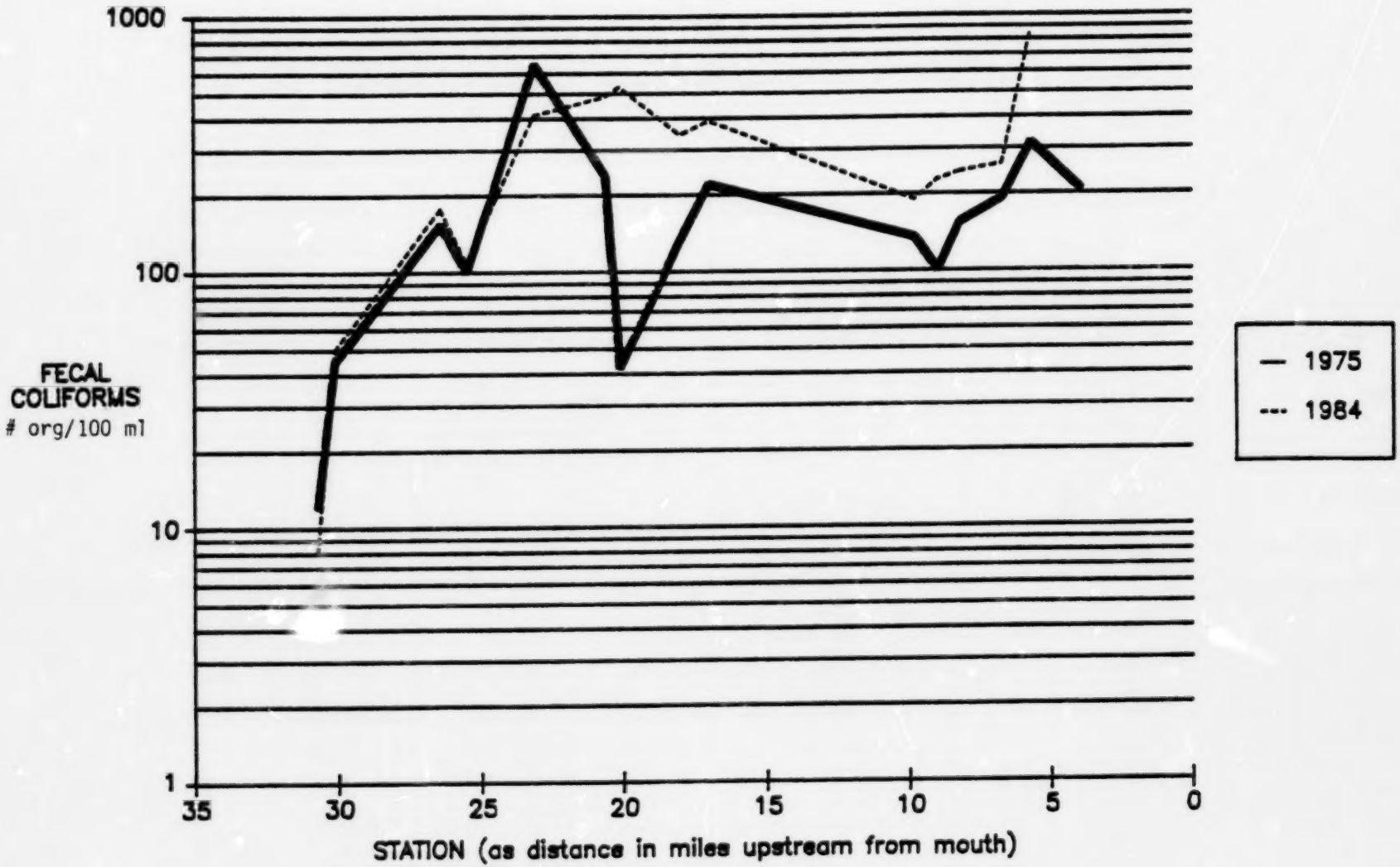

FIGURE 7. COMPARISON OF GEOMETRIC MEAN FECAL COLIFORM LEVELS 15 m OFFSHORE FOR 1975 AND 1984 cruises

Table 6
GEOMETRIC MEAN FECAL COLIFORM DENSITIES
OBSERVED[1] AT EACH STATION[2] FOR
1975 AND 1984

	Year		Change in Bacteriological Density ($p<0.05$)
	1975	1984	
Station: DT 30.7e	12	8	Decrease
DT 30.1e	45	50	Increase
DT 26.4e	154	177	"
DT 25.5	100	108	"
DT 23.1	649	412	Decrease
DT 20.6	237	487	Increase
DT 20.1	42	530	"
DT 18.0	133	343	"
DT 17.0e	220	389	"
DT 9.8	135	189	"
DT 9.0	100	227	"
DT 8.2	154	244	"
DT 6.7e	191	261	"
DT 5.7	316	861	"

NOTE: (1) Organisms/100 mL in samples taken 15 m offshore
(2) Except DT 3.9 for which no 1984 data exist

At each station, the geometric mean FC densities observed in 1975 were significantly different from those observed in 1984 at the 5% level. This indicates that the bacteriological quality of the Detroit River changed between 1975 and 1984. The last column in Table 6 shows the direction of change in bacteriological density, which was established on the basis of the difference in geometric mean FC densities. Based on the comparison of FC data from year-to-year (Figures 2 to 6) and the statistical analysis of fecal coliform densities for 1975 and 1984, it appears that the bacteriological quality of the Detroit River deteriorated between 1975 and 1984.

5.4 Impact of Precipitation

Depending on the intensity and duration of a rainfall event, the occurrence of rain immediately prior to and/or during sampling may impact bacterial levels observed in the river. Increased flows would be expected from all point sources and tributary streams resulting from runoff.

The total volume of rain recorded on the three days immediately prior to and during each cruise was obtained from the Atmospheric Environment Service of Environment Canada. The rainfall data represent gauge measurements recorded at the Windsor Airport. Table 7 presents a summary of the rainfall data collected. The highest rainfall recorded for a single sampling cruise (rainfall during as well as 3 days prior) was 49.6 mm, which occurred in July 1981. Cruises conducted in May 1975 and August 1982 were dry, with no rainfall recorded before or during sample collection.

Table 7
RAINFALL (mm) RECORDED 3 DAYS PRIOR TO AND DURING MOE BACTERIOLOGICAL MONITORING CRUISES

Year	Sampling Dates	RAIN (mm)		
		3 Days Prior	During	Total
1975	May 6 - 10	0	0	0
	July 14 - 18	16.5	0	16.5
	August 15 - 20	0	2.0	2.0
1978	June 26 - 29	13.0	19.0	32.0
	July 25 - 28	0	13.2	13.2
1981	May 30 - June 1	7.6	4.8	12.4
	July 28 - 30	16.8	32.8	49.6
1982	July 19 - 21	0	29.0	29.0
	August 16 - 18	0	0	0
1984	June 19 - 21	23.8	0	23.8
	August 27 - 29	0	4.4	4.4

Comparison of the rainfall during each cruise, shown in Table 7, with the bacterial levels shown in Figures 2 to 6, reveals a correlation between total rainfall volume and bacterial density. For example, the July cruises of 1975, 1981 and 1982 and the June cruise of 1984 recorded higher rainfall than other cruises undertaken during each of those years. Bacterial levels in the Detroit River during these cruises were also high in comparison to other cruises undertaken during each of those years. The volumes of rain and geometric mean fecal coliform densities recorded during both cruises of 1978 were similar in magnitude.

Although rainfall may have been related to the bacterial densities observed on different cruises within a particular year, there does not appear to be any definite correlation between rainfall volume and density from year-to-year. Specifically, fecal coliform densities were generally high for all stations (Table 4a) during the 1981 cruises, when the total rainfall was 62.0 mm (total, both prior to and during sampling, as shown in Table 7). The total rainfall volume for 1978 was 45.2 mm, which represents the second highest rainfall recorded for all years shown in Table 7. However, FC densities for all stations were generally lowest during 1978, relative to other years.

5.5 Impact of Distance Offshore

As indicated by the results presented in Table 4, distance from shore had a bearing on bacterial densities. Figure 8 shows the geometric mean fecal coliform density, calculated from annual geometric means, at each station for distances of 15 m and 60 m from the Canadian shore. With the exception of station DT 8.2, fecal coliform densities in samples taken 15 m offshore were consistently higher than FC densities in samples taken 60 m offshore. These results suggest that bacterial levels observed in the Detroit River result from contamination originating from point and non-point sources along the Canadian shoreline. Variation in fecal coliform densities with distance offshore appears to be consistent with distance downstream for most stations.

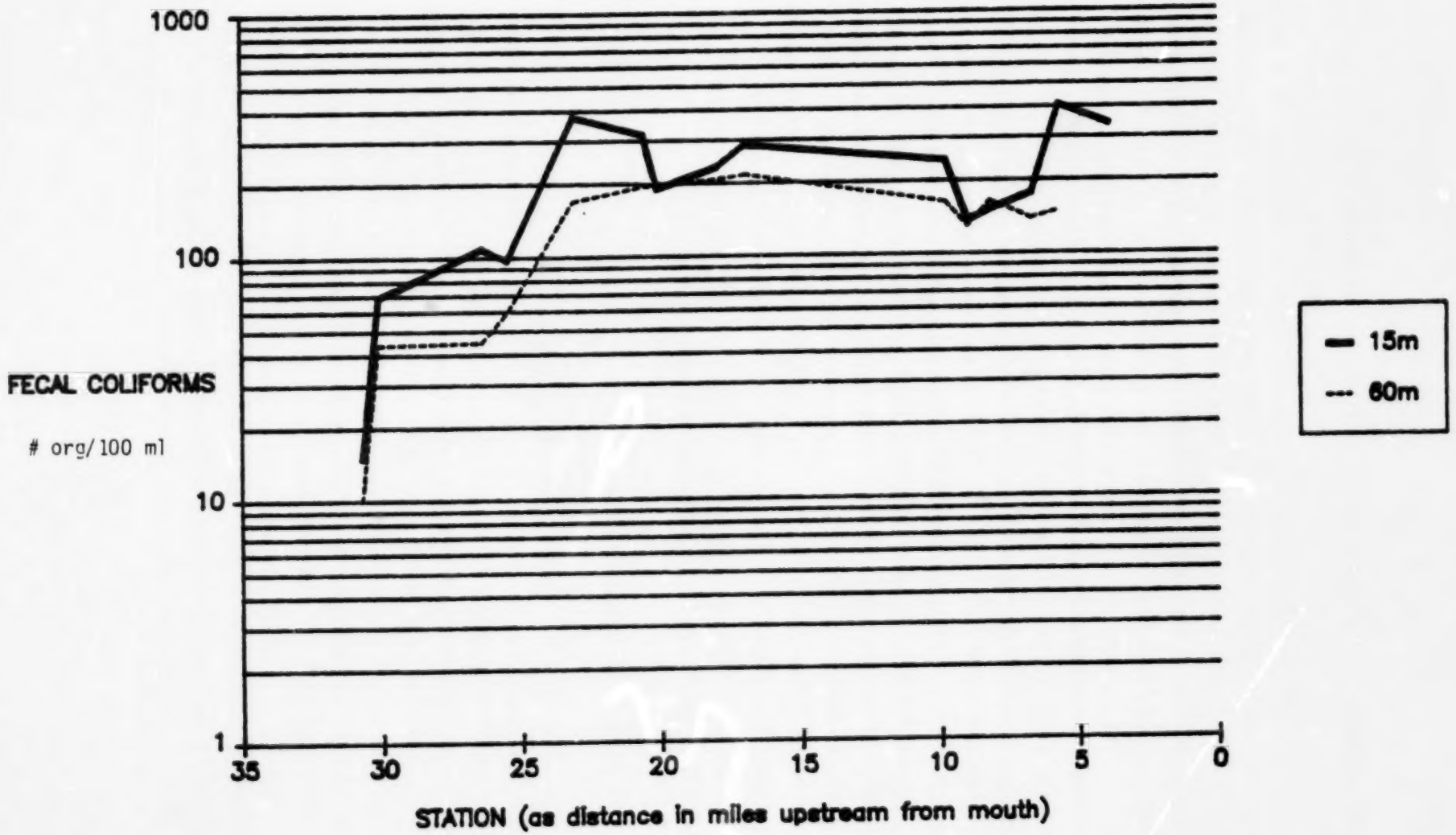

FIGURE 8. POOLED (1975 - 1984) GEOMETRIC MEAN FECAL COLIFORM DENSITIES AT 15 m AND AT 60 m FROM THE CANADIAN SHORE

5.6 Monthly Variation in Bacterial Densities

The time of year during which sampling is undertaken may have some impact on observed bacterial levels.

As shown in Figures 2, 4, and 5 for 1975, 1981 and 1982, samples collected during the July cruises yielded the highest geometric mean fecal coliform levels for most stations relative to other cruises undertaken during each of those years. For 1978, results obtained for the June 26-29 and July 25-28 cruises were similar, as shown in Figure 3. Geometric mean fecal coliform levels in samples taken during June 19-21, 1984 were, for the most part, higher than those observed for August 27-29, 1984.

Based on the data presented in Figures 2 to 6, the bacteriological quality of the Detroit River appears to be somewhat dependent on seasonality. Of specific concern is the fact that geometric mean fecal coliform densities observed 15 m offshore seem to increase as the summer, and hence swimming season, progresses.

6.0 ANALYSIS OF POINT SOURCES AND TRIBUTARY INPUTS ON BACTERIOLOGICAL QUALITY

Bacteriological data were also collected for each major source discharging to the river in each year (except 1981) in the periods that stream samples were collected. It should be noted that due to the limited amount of source data collected, the bacterial characteristics of each source may not be truly represented. Nonetheless, the data does provide a valuable understanding of source bacterial densities at the time of river sampling. As well, for the tributary streams such as the Little River and Turkey Creek, bacterial densities can be compared with Provincial Water Quality Objectives (PWQO).

Riviere aux Canards has not been included in the following analysis because there is no upstream station in close proximity to the confluence of the stream (see Figure 1 and Table 2) thus making impact analysis difficult.

6.1 Little River

Figure 9 presents FC densities for stream stations DT 30.7e and DT 30.1e upstream and downstream of Little River, respectively, and for the mouth of the Little River itself. Little River samples were taken in-stream, at its confluence with the Detroit River. Fecal coliform densities in the Little River exceeded the PWQO of 100 org/100 mL in the years 1978, 1982 and 1984. Indeed, in 1984 FC densities were an order of magnitude above the PWQO.

Student's t-statistics calculated for the upstream and downstream stations (pooled data 1978-1984) indicated that geometric mean fecal coliform densities (@ 15 m offshore) between stations above and below the Little River confluence were significantly different ($p \leq 0.05$). This implies that the Little River has an impact upon river bacterial quality.

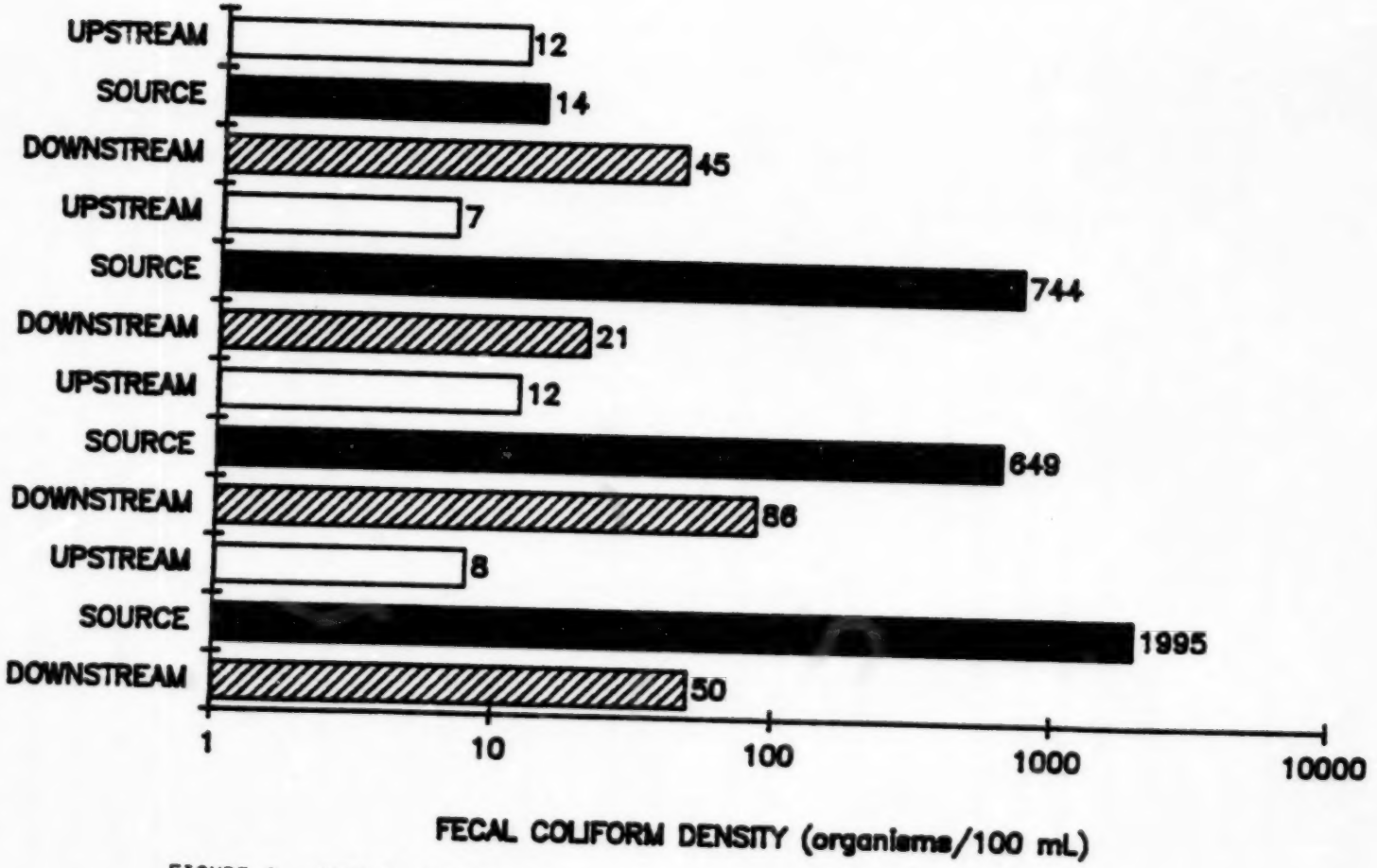

FIGURE 9. ANNUAL GEOMETRIC MEAN FECAL COLIFORM DENSITIES MEASURED AT THE MOUTH OF THE LITTLE RIVER AND IN THE DETROIT RIVER AT DT 30.7e (UPSTREAM) AND DT 30.1e (DOWNSTREAM) OF LITTLE RIVER (15 m OFFSHORE)

6.2 City of Windsor CSOs

Figure 10 presents geometric mean fecal coliform densities at stations DT 26.4e (upstream) and DT 20.6 (downstream) as well as FC densities for the City of Windsor CSOs. The CSO samples were collected from the sewer upstream of the CSO outfalls by City of Windsor Public Works staff. The conditions under which "CSO" samples were collected, such as flowrate within the sewer and exact sampling location, are not known. As a result, it is difficult to establish whether or not the "CSO" samples represent dry weather seepage, dry weather overflow, wet weather overflow, or a combination of these phenomena. Fecal coliform levels in the "CSO" samples ranged from 22 organisms/100 mL in 1975 to 1,470 organisms/100 mL in 1982.

A student's t-Test indicated that geometric mean FC densities at DT 20.6 were significantly higher than at DT 26.4e ($p \leq 0.05$). Higher bacterial levels recorded at the downstream station imply that discharges to the Detroit River within the reach of the City of Windsor CSOs are deleterious to River bacteriological quality.

6.3 West Windsor WPCP

Yearly geometric mean fecal coliform densities (@ 15 m offshore) upstream (DT 20.6) and downstream (DT 20.1), as well as from the West Windsor WPCP itself, are presented in Figure 11. Effluent samples from the WPCP were collected within the plant. Because chlorination of plant effluent is achieved via injection into the outfall pipe, samples represent effluent prior to disinfection.

Comparison of the FC levels at the stations upstream and downstream from the West Windsor WPCP shows that for all years except 1984, downstream bacterial densities were lower than upstream levels. Statistical analysis, using pooled yearly geometric means, indicated that FC densities were significantly different at the two stations, which suggests that the West Windsor WPCP had no adverse impact on Detroit

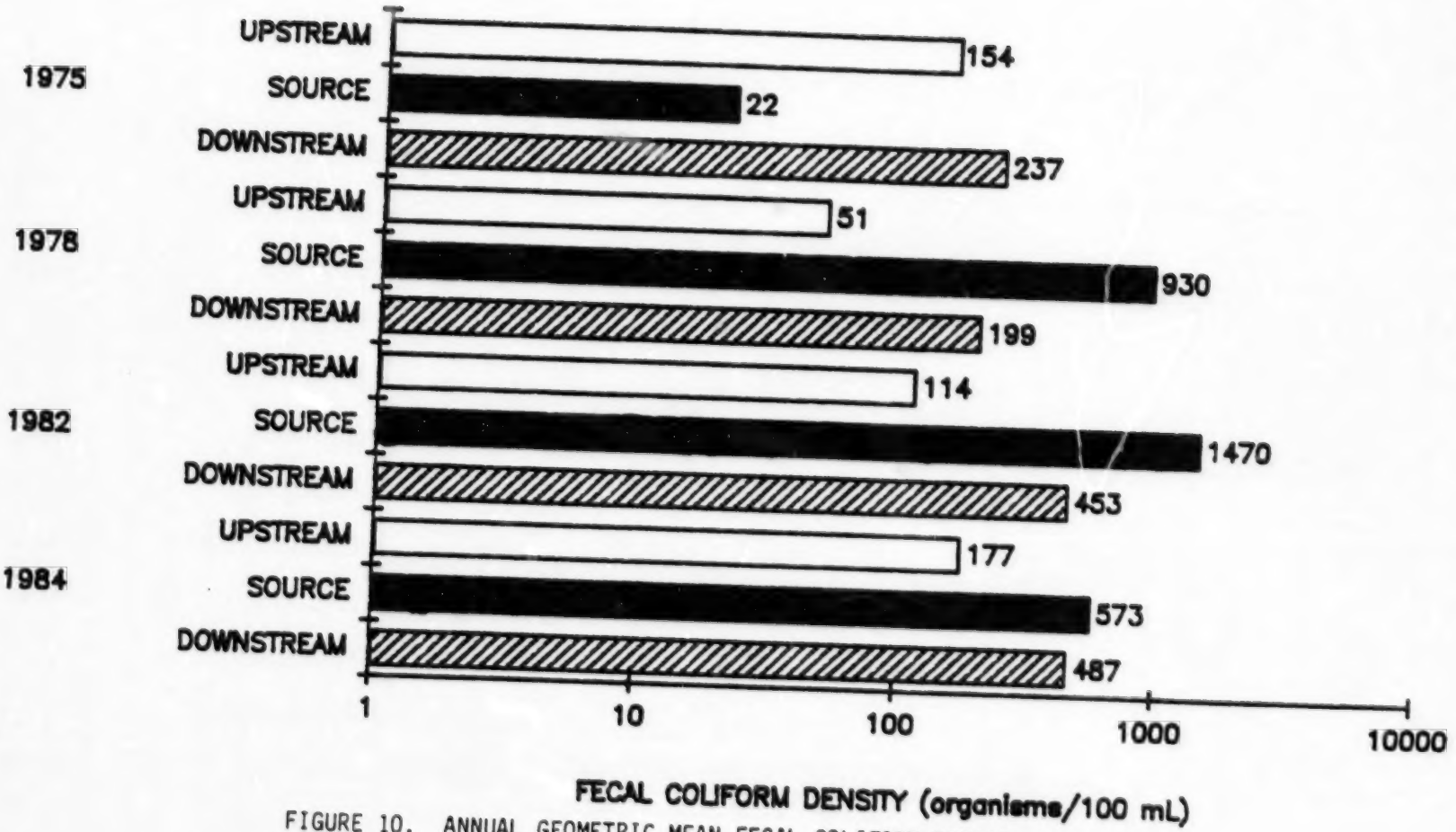

FIGURE 10. ANNUAL GEOMETRIC MEAN FECAL COLIFORM DENSITIES MEASURED IN THE DETROIT RIVER AT DT 26.4e (UPSTREAM) AND DT 20.6 (DOWNSTREAM) OF WINDSOR CSOs (15 m OFFSHORE)

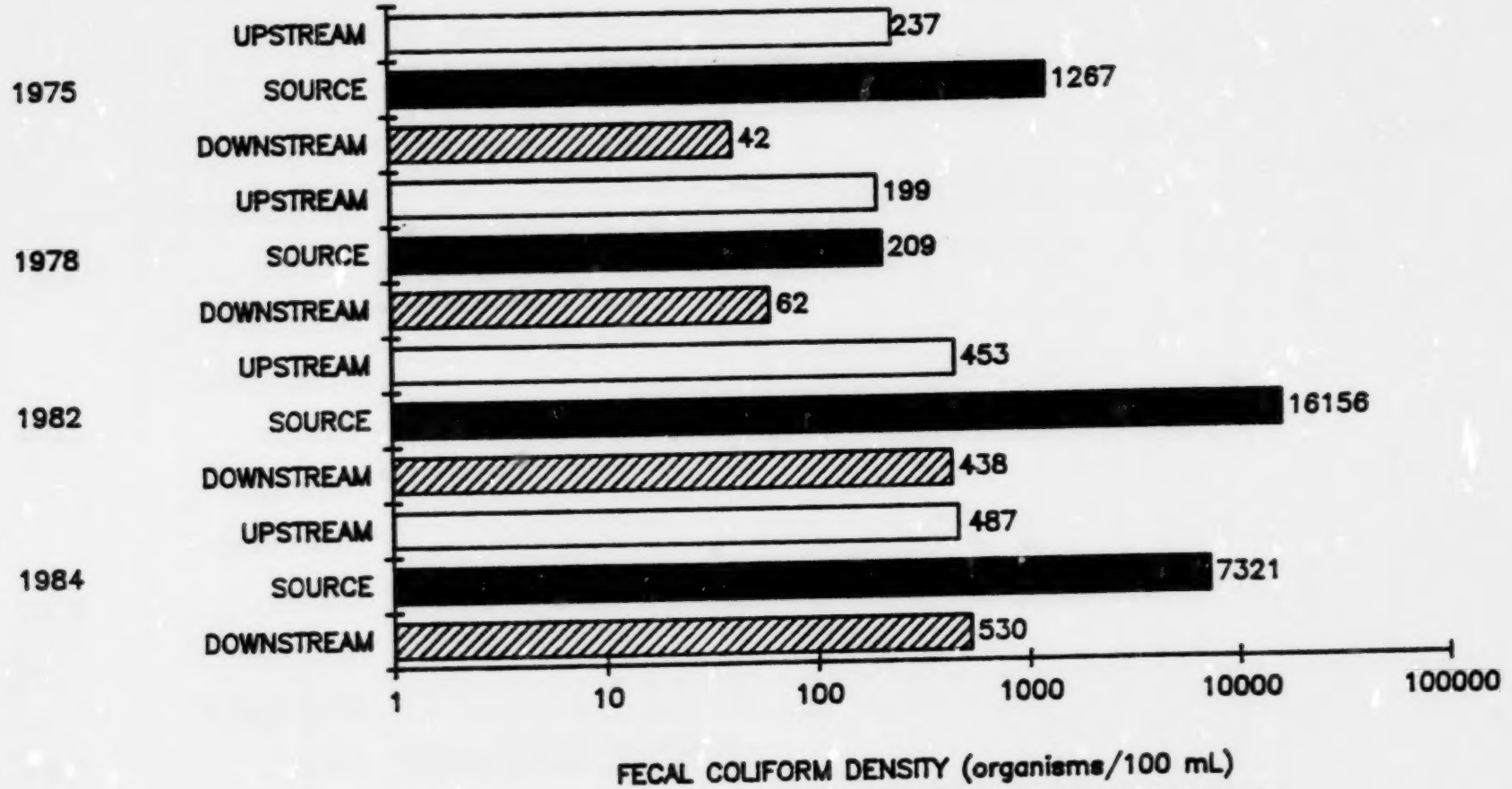

FIGURE 11. ANNUAL GEOMETRIC MEAN FECAL COLIFORM DENSITIES MEASURED IN WEST WINDSOR WPCP AT THE POINT OF DISCHARGE INTO THE DETROIT RIVER AND IN THE RIVER AT DT 20.6 (UPSTREAM) AND DT 20.1 (DOWNSTREAM) OF WEST WINDSOR WPCP (15 m OFFSHORE)

River bacteriological quality and it is possible that sufficient residual chlorine may have been present in the discharge from the plant to reduce downstream FC levels.

6.4 Turkey Creek

Figure 12 presents annual geometric mean FC densities (@ 15 m offshore) for DT 18.0, DT 17.0e and Turkey Creek at the point of discharge into the Detroit River. As was the case with Little River, Turkey Creek samples were taken in-stream at its confluence with the Detroit River.

Fecal coliform densities measured at the mouth of Turkey Creek ranged from 1,011 organisms/100 mL in 1984 to 10,036 organisms/100 mL in 1982. These densities represent violations of the Provincial Water Quality Objective (100 FC/100 mL) by over one and two orders of magnitude, respectively. With the exception of results shown for 1982, FC densities downstream from Turkey Creek were only marginally higher than FC densities observed at the upstream station. Analysis of geometric mean FC levels for all years shown in Figure 12 did, however, indicate that the difference between upstream and downstream observations was statistically significant ($p \leq 0.05$).

6.5 Amherstburg WPCP

Geometric mean FC densities upstream, downstream and at the Amherstburg WPCP are presented in Figure 13. Effluent samples were collected within the plant; however, it is not known whether these represent effluent before or after chlorination.

With the exception of 1978, annual geometric mean fecal coliform densities observed in the effluent discharged from the Amherstburg WPCP were higher than any of the other sources monitored by the MOE during these surveys. It should be noted that data for 1978 (170 fecal coliforms/100 mL) represent samples taken during a June survey only. Geometric mean FC densities of 29,695 organisms/100 mL and 875,253 organisms/100 mL in the treatment plant effluent for 1982 and 1984 respectively, appear to confirm historically poor performance (see Kinkead and Hamdy, 1976). Fecal coliform levels downstream from the

Amherstburg WPCP have been consistently higher than those observed at the upstream station. Statistical analysis, comparing geometric mean FC densities at DT 6.7e (upstream station) and DT 5.7 (downstream station), indicated that the difference in FC levels for the two stations was significant. However, downstream FC densities have not been dramatically higher than those observed upstream with the exception of 1984 data, which shows an increase of approximately one half log unit.

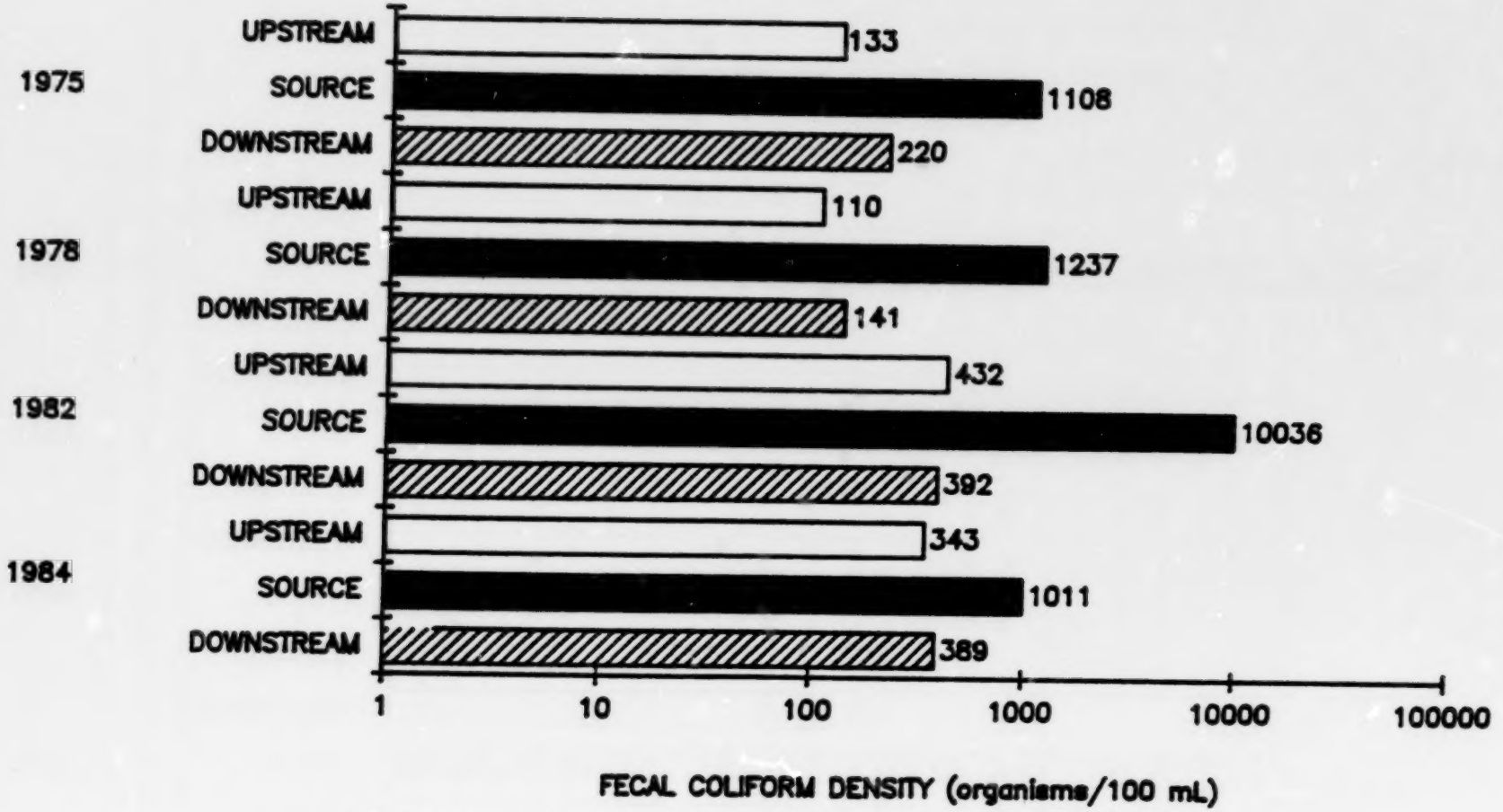

FIGURE 12. ANNUAL GEOMETRIC MEAN FECAL COLIFORM DENSITIES MEASURED AT THE MOUTH OF TURKEY CREEK AND IN THE DETROIT RIVER AT DT 18.0 (UPSTREAM) AND 17.0e (DOWNSTREAM) OF TURKEY CREEK (15 m OFFSHORE)

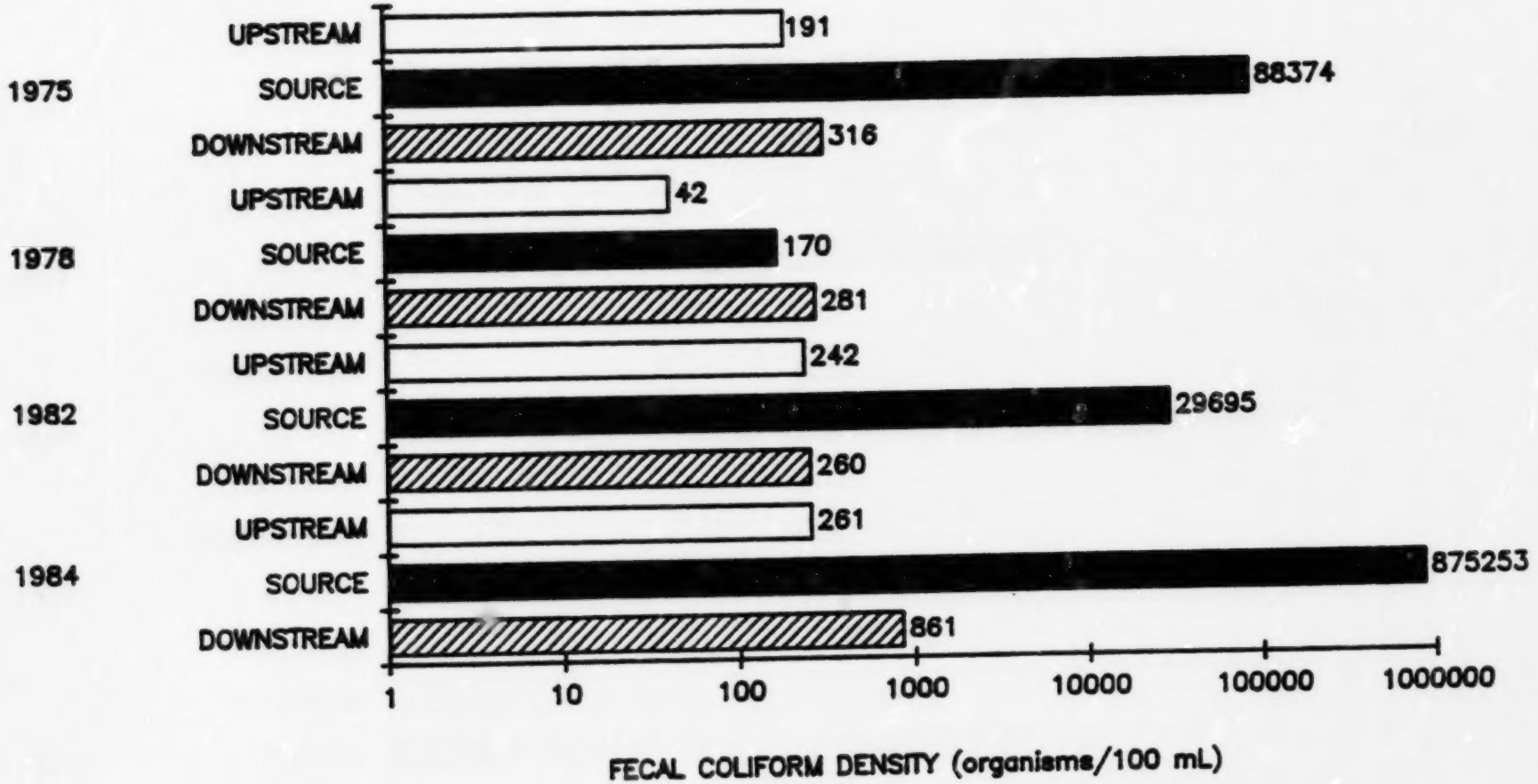

FIGURE 13. ANNUAL GEOMETRIC MEAN FECAL COLIFORM DENSITIES MEASURED IN AMHERSTBURG WPCP AT THE POINT OF DISCHARGE INTO THE DETROIT RIVER AND IN THE RIVER AT DT 6.7e (UPSTREAM) AND DT 5.7 (DOWNSTREAM) OF AMHERSTBURG WPCP (15 m OFFSHORE)

7.0 SUMMARY AND CONCLUSIONS

7.1 Historical Water Quality

Based on an analysis of data collected between 1975 and 1984, it appears that, in general, the bacteriological quality of Canadian waters of the Detroit River has deteriorated. Analysis of fecal coliform densities (@ 15 m offshore) observed at consecutive sampling stations for 1975 and 1984 indicated significantly higher levels in 1984 than in 1975. Geometric mean fecal coliform and fecal Streptococcus densities (15 m offshore) in 1975 ranged from 12 to 649 organisms/100 mL and from 4 to 87 organisms/100 mL, respectively. Minimum and maximum densities in 1984 were 8 and 861 organisms/100 mL for fecal coliform and 8 and 96 organisms/100 mL for fecal Streptococcus. The frequency with which the Provincial fecal coliform objective (100 organisms per 100 mL) was exceeded increased from 66.7% (10 of 15 stations) in 1975 to 85.7% (12 of 14 stations) in 1984. Bacterial densities tended to increase with increasing distance downstream. At the two furthest upstream stations, violations were recorded during one monitoring period only, whereas geometric mean fecal coliform levels were greater than 100 organisms per 100 mL at the stations nearest the mouth of the River in each of the five years during which samples were collected.

7.2 Factors Affecting Bacteriological Quality

Analysis of FC levels with increasing distance from shore suggested that bacterial levels observed in the Detroit River resulted from contamination from sources along the Canadian shore. A comparison of the geometric mean fecal coliform densities, calculated from yearly means, at 15 m and at 60 m showed that nearshore levels were typically higher than those observed further offshore.

The impact of precipitation on Detroit River bacteriological quality could not be unequivocally established. The highest fecal coliform levels were recorded for the cruise conducted during July 28-30, 1981.

Rainfall for this time period was also the highest recorded during any of the cruises. However, the lowest FC levels coincided with the second highest rainfall volume, recorded in 1978.

The bacteriological quality of the Detroit River also appears to deteriorate as the summer progresses. Monthly variation in bacteriological quality was examined using fecal coliform densities observed at 15 m from shore. Samples collected during late June or July contained higher densities than those collected in May/early June.

The relatively poor bacteriological quality of the Detroit River may be due in part to discharges from known point sources and tributary streams discharging into the River, including flow from the Little River, City of Windsor CSOs, flow from Turkey Creek, and effluent from the Amherstburg WPCP. With the exception of the West Windsor WPCP, fecal coliform densities observed in the river at stations downstream from each point source have generally been higher than those measured at the corresponding upstream stations. Statistical analysis of the relationship between observed FC density and sampling station location indicated that point source inputs to the River had a significant impact on bacteriological quality.

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